THE ETHNOBIOLOGY OF LAC SCALE (*TACHARDIELLA* SPP.) IN THE ARID SOUTHWEST

by

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DEDICATION

To my brother, John K. Pool,
for encouraging me to carry on until the very end

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ABSTRACT

This research is an examination of the lac scale insect in the arid Southwest, its distribution, and its cultural uses. Three species, *Tachardiella fulgens*, *Tachardiella larreae* and *Tachardiella pustulata* are those most known to have been utilized by the indigenous peoples of the region from as early as the Archaic period to the modern era as an adhesive, mastic, and coating for the fabrication of tools, weapons, musical instruments, kicking balls, ornaments, and amulets. It was also used for hermetic sealing of containers to protect foods and seeds from pests and as a repair material for mending pottery.

The purpose of this research has been to broaden the current understanding of the biology and ecology of lac insects in the arid Southwest to elucidate more about indigenous cultural uses and traditional ecological knowledge of these materials in the region over time. By documenting known distributions of the insects, their host plants and manufactured materials, data has been gathered for analysis to search for meaningful relationships. Ultimately, the biological and anthropological investigation of lac scale exudate sources, distribution, extent of use, and of possible circulation through trade has further illuminated its cultural significance. This research has expanded the previously known boundaries of the distribution of both the *Tachardiella* species and the range of peoples who utilized them to manufacture cultural materials in the arid Southwest. The data gathered have formed a foundation from which to expand research with further resources for more detailed biological and chemical analysis, and ethnohistorical research.

CHAPTER 1

Introduction

Several species of *Tachardiella*, lac scale insects, live in the arid Southwest as sessile phloem feeders on a variety of different host plants from various families. The insects produce a hard, waxy resinous coating as a defense mechanism from predators. The insects live in a multitrophic system in facultative mutualistic relationship with ants that guard the scales from predators (Gullan and Kosztarab 1997). The host plants of *Tachardiella* species produce several volatile chemicals, or secondary metabolites, which possibly play a role plant and insect coevolution (Garcia Morales et al., 2016). With all of the interactive variables at play, these lac scale live in a very complex ecological niche that is not yet well examined or understood (Kondo and Gullan 2011). To provide context for this research, in the following pages, I briefly describe the history of study of lac scale insects globally, before focusing on historical studies of lac scale insects in the desert regions of North America, with an emphasis on Arizona. Finally, I provide an overview of each of my dissertation chapters that follow from, or were inspired by, these historical studies.

With advancements in analytical tools for materials characterization such as Fourier Transform Infrared Spectrometry (FTIR) researchers have been able to correctly identify the lac exudate in museum artifact collections (Bisulca et al., 2017). Likewise, with advancements in digitization, anthropological museums, herbaria, and entomology collections have been able to make their collections accessible online, usually with accompanying photographs. Examination of a number of these resources both in person and online have shown that the lac exudate is most often unidentified or incorrectly identified, which keeps the material in obscurity within biological and anthropological research (Bisulca et al., 2017). Even when lac was properly

identified by the collector, that information was often not transposed to catalog records. Further contributing to the scarcity of knowledge around lac is that most research of the lac insects, host plants, and their ecology are centered around the species found in Asia, where they are commercially produced for industrial applications. Molecular phylogenetic studies are also focused on the Asian Kerria species (Chen et al., 2013), but little is known about lac insects in other parts of the world.

Tachardiella is one of ten genera inclusive of one hundred and one species in the family Kerriidae: order Hemiptera; suborder Sternorryhncha; superfamily Coccoidea (Ben-Dov 2006; Garcia Morales et al., 2016; Kondo and Gullan 2022). A French Jesuit Priest named Tachard was the first European to describe the Asian lac scale in 1709. The lac scale insect family was temporarily named after Father Tachard and went through several iterations including Laccifer, Carteria and Kerria (Gibson 1942; Garcia Morales et al., 2016). Since 1998 the lac scale family name has been Kerriidae, after James Kerr (Ben-Dov 2006). Kerr was a British medical officer in India who published a biological description of *Coccus lacca* (*Kerria lacca*) called the "Natural History of the Insect which produces the Gum Lacca" which included details about the four host tree species known at the time. Kerr also described the manufacturing processes from raw stick lac to finished products including jewelry, sealing wax, polish, varnish, paint, and dye (Kerr 1781). Today, commercially produced lac is used for the same purposes, but with less emphasis on dye, and more use for industrial components, varnishes, food coatings and cosmetics (Kumar et al., 2015). A full description of Kerriidae nomenclature, systematics and a catalog of genera and species is found in Ben-Dov (2006) and Garcia Morales et al. (2016).

The seventeen lac scale species found in the Americas are grouped in the genus *Tachardiella*, retaining the reference to Father Tachard. The first of the seven species known

from North America was described in 1880 by J.M. Stillman, the eventual head of Chemistry at Stanford University. The lac Stillman found growing in Arizona was reported to grow on *Larrea mexicana* and *Acacia greggi*. He concluded that the "gum-lac" of Arizona, like that from India, was the result of an insect (*Coccus lacca*) puncturing a host plant and producing the exudate, and not produced by the plant, as was widely believed at the time (Stillman 1880). Stillman also believed the lac exudate was like but not the same as Indian lac.

In 1881, J.H. Comstock, while chief entomologist for the U.S. Department of Agriculture, published the first biological descriptions of two species of North American lac scale, the first which he called *Carteria larreae*, later changed to *Tachardiella larreae.* The host plant was the creosote bush, then called *Larrea Mexicana*, later *Larrea tridentata.* Comstock restated Stillman's finding that the resin was an insect exudate and not a product of the host plant. He also suggested that Arizona lac could be economically important due to the prevalence of creosote bush, assuming it would be as common as the host plant (Comstock 1881:212). The USDA report also noted that the Pima Indians (Akimel O'odham) used the lac to form balls for kicking while on trails (Comstock 1881:782). The second species was found from the collections of the Museum of Comparative Zoology at Harvard. It was collected in Tampico, Mexico from a mimosa plant. Comstock named this species *Carteria mexicana*, which later became *Tachardiella mexicana* (Comstock 1881, 1882, 1916).

Another species of *Tachardiella* from the Southwest was first published in 1894 by Theodore Cockerell, a zoologist working for the New Mexico Agricultural Experiment Station at the time. The lac scale, *Tachardia cornuta,* was collected in the Mesilla Valley area near Las Cruces, New Mexico from an unidentified host plant in the Compositae (Asteraceae) family. This host plant was probably American tarwart (*Flourensia cernua*) the predominant host for the

species now called *Tachardiella cornuta* (Cockerell 1894:284). Cockerell published two more species of *Tachardiella* the following year (Cockerell 1895, 1895a, 1895b). The first was *Tachardia fulgens* (*Tachardiella fulgens*) and the second was *Tachardia pustulata* (*Tachardiella pustulata),* which he described as being the color of black currant jelly. Cockerell (1895a) noted that the *T. fulgens* specimen was acquired from a Mexican man who said it was "*Gomea*" that was used as a medicinal for stomach ailments and was sold as such by Tucson druggists. He also mentioned it was used to repair pottery. He stated that *T. larreae* was not known to have medicinal properties. (Cockerell 1895a:2). Cockerell published additional reports on lac insects throughout his career (1903, 1904, 1924, 1945).

Joseph C. Chamberlin, while an entomology student of Gordon F. Ferris at Stanford University, published a monograph on the subfamily Tachardiinae of lac insects to bring together all the various individually published species, to provide complete morphological descriptions, and to resolve the classification for the many genera and species, ultimately creating the first key to the species in genus *Tachardiella* (Chamberlin 1923, 1925; Kondo and Gullan 2011). In his discussion of the *Tachardiella* species, Chamberlin notes that while *T. larreae* was at one time thought to be commercially viable, the idea had since been disproved. Chamberlin was no doubt referring to field work conducted by Gordon Ferris, who studied the distribution of *T. larreae* on creosote bush by driving from California to New Mexico and back and up the Colorado River searching for the elusive insect. He concluded the presence of lac was sparse, except around the Colorado River area and was not in enough abundance to be economically viable (Ferris 1919).

Like Ferris before him, who sought a viable American source for lac in the World War I era, Dr. Harold Colton, a zoologist, anthropologist, and founder of the Museum of Northern Arizona (MNA), and staff from the Museum began a three-year project to conduct a formal

biological survey to determine the distribution of the insect (Colton 1943b). Colton wanted to establish whether *T. larreae* could be found in sufficient quantity in Arizona to support commercial production to replace shortages in lac due to World War II. The War hindered shipments from India and cut off domestic availability in the United States. Colton's first expedition took place in October 1942. He, his wife, and an assistant drove from Flagstaff to Kingman and set up 11 plots and 2 stations along Rte. 66 west of Kingman, each plot measuring 10,000 square feet. They collected lac specimens, recorded the percentage of infestation of plants per plot and collected ants they found around the lac scale. Colton typed up a list of questions he wanted to answer about the lac, three of them concerning the ants. Colton reported the species of the ant was *Crematogaster atra* (Colton 1943a).

Figure 1 "Lac Expedition October 28, 1942." Dr. and Mrs. Harold Colton and assistant on lac survey and collecting trip. Photograph from the Colton Family Collection, MS 207-115-1, Courtesy of the Museum of Northern Arizona.

On the second expedition in February 1943, Colton took a larger crew to Kingman to revisit the original stations to record how much time it took each person to collect a pound of lac. Additional expeditions in April and August 1943 covered a wider geographic range where they established other stations throughout Arizona. They also made observations in Southeastern California, Southern Nevada and in Northern Sonora, Mexico. On the last expedition they set up experiments for lac propagation in Mohave County by tying lengths of sticklac with waxed string to non-infested stems of *Larrea tridentata.* Only a few of the propagation attempts succeeded. They found that the ants snipped the strings causing the sticklac to fall off, being good defenders for their honeydew rewards.

An article, "Lowly Desert Greasewood Source of Valuable Resin," found in the Colton Manuscripts at MNA from the periodical *Arizona Farmer* (1943) refers to creosote bush (*Larrea tridentata*) as greasewood, calling it a worthless desert plant, ironically suggesting that it has a gum that can replace lac from India. It notes that Dr. Paul Burgess, then the Dean of the College of Agriculture at the University of Arizona and Dr. William E. Martin, a horticulturist, also from the University of Arizona, brought attention to the material when they sent samples of the plant and insect exudate to the National Paint, Varnish and Lacquer Association (NPVLA) for analysis. The results of the analysis were published the previous year in a circular for the NPVLA (Gardner and Sward 1942). The article briefly mentions and illustrates the insect exudate but focuses on the analysis of the resin produced by the plant and its potential for commercial uses as a varnish, insecticide, paint, and other materials.

In 1943, Dr. Colton sent samples of *T. larreae* sticklac from his lac survey expeditions to NPVLA for analysis of the insect exudate. Mark Westgate's report on the analysis was included with a cover letter dated June 18, 1943 (Colton 1943a). The report was later published in a

NPVLA circular (Westgate 1943). According to the report, Arizona lac's primary components were 23.5% resin, 51.9% wax and 23.7% residue. In comparison to Indian shellac (*Kerria lacca*), it had low solubility in alcohol and was persistently tacky on the surface, and therefore was an unsuitable substitute for the Asian lac exudate. Westgate (1943) indicated that *T. larreae* had greater tensile strength and less flow capability necessary for varnishes and coatings, likely due to the higher wax and lower resin content.

Colton (1943b) also published the distribution survey results. They found at least 50 creosote plants contained lac at each of the 147 sites surveyed in eastern California to southern Arizona and into Nevada and Sonora, Mexico. The greatest density was found in the Sacramento Valley and Mohave Valley south of Rte. 66, where there were 39 stations with 13.6% infestation. The greatest abundance was found inland from the Colorado River, south of Kingman down to the Yuma area. Other sites in Yuma County north of the Gila River and farther south of the Gila River were less dense. Colton's results concurred with those of Ferris before him, that the greatest abundance of *Tachardiella larreae* was found in the Colorado River area. The following Arizona counties had *T. larreae*: Yuma, Pima, Maricopa, Pinal, and Yavapai. None was found in Graham, Gila, or Cochise Counties or East of the Rio Grande in New Mexico (Colton 1943b:23).

As with Ferris, Colton's distribution study found populations to be insufficient for commercial production (Colton 1943b). Colton also noted the continued dearth of published research on the American lac species, particularly regarding the life history of the insects. In spite of the disappointing results of the evaluation of the economic viability of *Tachardiella larreae,* Colton's expeditions succeeded in defining the distribution of the insect in Arizona and other localized parts of the Southwest at the time and inspired his examination of the characteristics of the insect, including morphology and life history, later updated more broadly

by Gullan and Kondo (2007). The following year Colton (1944) wrote his monograph on the anatomy of female *Tachardiella larreae.* In the forward he mentioned an archaeological excavation in 1939 of the Ridge Ruin near Flagstaff, Arizona where turquoise mosaic ornaments were found in a burial. The mosaics were adhered with a material determined to be insect lac by University of Michigan botanist Volney Jones (Colton 1944). Raw sticklac, and molded lac on sticks were also found at the site (Colton 1941b). In the report on the excavation the authors noted that their discovery was the first documented archaeological use of insect lac in the region (McGregor et al., 1941). Learning that insect lac was used for mastic in the manufacture of turquoise mosaic in the Southwest was particularly intriguing to me. The desire to understand more about the material, its cultural uses and its distribution in the region inspired me to pursue a doctoral degree in the subject.

The current distributions of all species of *Tachardiella* found in the arid Southwest are discussed in detail in Chapter 2 along with the distribution of their predominant host plants. Detailed descriptions of the three species of *Tachardiella* most often found as components of manufacture for cultural use in museum collections and described in the literature are also presented in this chapter. Initially, this research sought to address the speculation that distribution of the different lac host plants affects the abundance of lac available for cultural exchange. If *Tachardiella larreae* was rare and difficult to procure, it may have been that the primary source for lac for trade was instead *T. fulgens* and/or *T. pustulata.* This hypothesis was intended to be tested by examining the physical distribution of the host plants and the known locations for the different lac species from biological collections, museum artifacts collections with lac and with published data. I surmised that greater understanding of the biology and ecology of lac scale insects would illuminate more about the source species of these materials,

their possible origin locations and clarify their distribution by trade over time through the various culture groups in the region.

In the process of gathering data on *Tachardiella* spp. distribution from entomological, botanical and eventually anthropological sources, original assumptions about the extent of distribution have been challenged, initially thinking that *Tachardiella* spp. lived only below the Mogollon Rim and would have been exchanged to the North from the South. Research findings now show that *Tachardiella* spp. live as far north as southern Nevada and southern Utah and speculation and assumptions about likely trade routes have been altered. Since lac availability was more widespread inclusive of the three species known to have cultural uses, it is now thought that trade routes were more localized than long distance in the region.

In the discussion of the classification and description of genus *Tachardiella* above, there are several instances of authors mentioning cultural use, both historically and in the last example, archaeologically. Indigenous peoples of the arid Southwest found great utility in the hard lac exudate of the *Tachardiella* species. Early applications included using lac for hermetic sealing of foods in ceramic jars and gourds; for coatings and repair materials; and for producing weapons, tools, and ornaments. Chapter 3 addresses part of the overall research problem in correctly identifying insect lac exudate by examining problems with terminology and nomenclature in describing resinous and non-resinous adhesive materials in a cultural material context. It also provides a review of anthropological literature and examples of archaeological material culture with lac used as a component in manufactured artifacts found in museums and repositories in the arid Southwest. Finally, Chapter 3 addresses research questions regarding the cultural knowledge and use of insect lac in the region, considering local production and possible extent of trade routes through time.

Chapter 4 provides a review of ethnographic literature and examples of historical material culture with lac as manufacturing components in artifacts found in museums and repositories in the arid Southwest. One of the major challenges in using museum collections for research is poor documentation, whether its absence in museum records or perhaps worse, misinformed documentation regarding affiliation, materials, technology, and for both cultural and biological objects, provenience, where they came from. When there is misinformation in the documentation the assumptions made about the material identity, cultural affiliation or species can be repeated in multiple publications (Fox and Sutton 1995:363). For example, multiple scholars used generic terms for resins found on artifacts calling them gum, which is not a resin at all. There was confusion between plant and insect exudates, as well as confusion over insect exudates between true lac produced by *Tachardiella* spp. and a wax producing scale in Mexico called *Llavein axin.* As discussed earlier, nomenclature and systematics perpetually changed through the twentieth century, not only for lac scale species but also their host plants.

The problems of misidentification and perpetuation of misinformation in the literature and in museum catalog records are discussed in both Chapters 3 and 4.

Chapter 5 explores the Comcáac (Seri) people's relationship to their environment, adaptive strategies including traditional ecological knowledge (TEK), employed to respond to rapidly changing conditions in the modern era. Comcáac material culture and their use of insect lac will be examined as one manifestation of TEK to document continuity, exploring some of those adaptive strategies for survival in Comcáac culture. Additional cultural information not found in the literature was sought from a scholar with experience and research specialization with the Comcáac through a questionnaire and interview, and supplements the other research presented in this chapter.

Chapter 6 examines the biochemistry and function of the anthraquinone pigments carminic acid and laccaic acid produced by the cochineal scale (*Dactylopius* spp.) and lac scale (*Kerria lacca)* respectively. Each scale biosynthesizes its distinct pigment and does not acquire the chemicals from the phloem of its host plants. The functional roles of these pigment chemicals have been studied in the past but are not yet completely defined or understood. This review provides context for the history and geography of human use of carminic acid and laccaic acid, an overview of the two scale insects and their ecology, discussion of the biochemical literature on the two pigments and analysis of the research regarding their functional role. While both pigments were historically valued dye commodities, interest in their use as colorants and anti-bacterial preservatives persists today, justifying further analysis to elicit a more a complete explanation of the biological function of pigment production in these scale insects.

Chapter 7 describes recent techniques and advancements in analysis for materials characterization, progressing from microchemical tests and examination by Ultraviolet light to Fourier Transform Infrared Spectrometry (FTIR), and gas chromatography mass spectrometry (GC-MS), which researchers have been able to use correctly identify the lac exudate in museum artifact collections (Stacey et al., 1998; Sutherland and Del Rio 2014; Bisulca et al., 2017). A discussion of the processes used to analyze lac containing objects as part of this research is provided, including comparison of recently obtained GC-MS analysis of samples of raw lac collected in the field and samples taken from archaeological mosaics will also be presented and discussed. Consideration of future analytical techniques that will enhance our understanding of lac also are described. Chapter 8 presents general conclusions from all of the research that was conducted as part of this dissertation.

CHAPTER 2

Distribution of *Tachardiella* spp. and their primary host plants in the arid Southwest

Introduction

There are seven species of lac scale insects reported in the arid Southwest, all of which are sessile phloem feeders on several woody host plants from various families, reported in the arid Southwest (Kondo and Gullan 2011). The three species most associated with cultural use are *Tachardiella fulgens, T. larreae,* and *T. pustulata*. A fourth species, *T. ferrisi*, also has been referenced in the literature as an adhesive for rattles called "chamise pitch", used by the Kumeyaay in Southern Californian (Hector 2018:7). The three other species found in the Southwest (*T. cornuta*, *T. glomerella*, and *T. mexicana)* are not found referenced as a cultural material in the literature and are not yet identified on objects of material culture. This chapter provides a comprehensive overview of the three *Tachardiella* spp. most associated with cultural use, their distribution, including details about their distributions, and the distributions of their most prominent host plants.

Background

The following tables and figures provide an overview of the classification, appearance, and habitat *Tachardiella fulgens, T. larreae,* and *T. pustulata*, and their primary host plants. There is a rich variety of common names in indigenous languages, English and Spanish for these species (Tables 1-3). The primary host plants are the predominant species found in botanical, entomological and anthropological collections containing *Tachardiella* spp. and are also the same species referenced as host plants in the anthropological literature (Figures 1-7). The appearance of *Tachardiella* differs between these species as illustrated in the figures below, with

lac from *T. larrea*e a deep red, *T. fulgens* a deep orange, and *T. pustulata* a dark maroon color. Lac pigments will be discussed in further detail in Chapter 6.

Methods

The distribution data of *Tachardiella* spp. were gathered from a variety of sources. In 2015, early in this research, Christina Bisulca and I visited the University of Arizona insect collections to examine *Tachardiella* specimens. We also reviewed the host plant collections for *Tachardiella* spp. at the University of Arizona Herbarium in 2016, where we found *T. fulgens, T. larreae* and *T. pustulata* on four different plant specimens. The lac was noted by the collectors but not included in herbaria records. Given the onset of the COVID-19 pandemic, plans to visit other biological collections in person were dashed. Fortunately, many more entomological and botanical collections have since become accessible through online networks. Searches revealed that *Tachardiella* spp. is either not present in many entomological collections or hasn't been given priority for uploading to the network systems at this time. For example, a search on *Tachardiella* on the SCAN network, which contains specimens from hundreds of entomology collections around the United States and globally, only yielded seventy-six specimens. Searches for *Tachardiella* spp. on both the GBIF and iDigBio networks yielded the same number of results. The University of Arizona's specimens I examined were not listed, indicating that the collection data uploaded to the network was not complete. I suspect this is true of other entomological collections. The data that is available, however, provides a foundation for species distribution that may be expanded in the future with additional data.

I proceeded to search individual institution's entomology collection databases on their websites and was able to find additional *Tachardiella* specimens that included location data. Next, I searched online botanical collections with images of specimens of the three primary host

plants and was able to identify additional specimens of *Tachardiella*. While searching the larger online networks, I noticed that many occurrences did not come from institutions with biological collections, but instead came from iNaturalist observances.

iNaturalist is an online social network app founded in 2008 that was jointly taken on by the California Academy of Sciences and the National Geographic Society by 2017. It operates as a crowdsourcing tool to record and verify identification of observances of biological organisms in the field (iNaturalist 2022). The first observances of *Tachardiella* spp. appeared on the network in 2017. Since then, 112 specimens have been recorded. Given that each specimen has a photograph on the host plant accompanying locational data it has been straightforward to corroborate the observances. When multiple users corroborate the specimen identification it is considered "research grade." Table 7 illustrates the distribution of *Tachardiella* spp. by state and county observed by iNaturalist participants from 2017 to July 2022. The observances predominantly consisted of *T. fulgens* and *T. larreae*. Two specimens of *T. ferrisi* were observed in Southern California living on *Adenostoma fasciculatum*. It is notable that no specimens of *T. pustulata* have yet been recorded anywhere. Accessing the iNaturalist data more than doubled the number of specimens of *Tachardiella* spp. from which to draw location data, and unlike many of the collection specimens, all records had location data.

Results

Table 1: Classification of *Tachardiella fulgens* and its primary host plant, *Coursetia glandulosa* (Bennett & Zingg 1935:145, 170; Euler & Jones 1956; Sutton 1995; Ben-Dov 2006; Moser & Marlett 2010:184, 373; Kondo & Gullan 2011; Bye 2016).

Lac scale species		Primary host plant species
Tachardiella fulgens (Cockerell)		*Coursetia glandulosa* A. Gray
Order	Hemiptera	Fabales
Suborder	Sternorrhyncha	
Family	Kerriidae	Fabaceae
Superfamily	Coccoidea	
Common Names		
English		Rosary Babybonnet
Spanish	Samo prieto	Sámota, Samo
Tarahumara (Rarámuri)	Alí, Axin, Aje, Arí	
Seri (Comcáac)	Csipx	Hehe ctoozi, Sámota
Pimeria Alta, Opata	Xuarí, Juarí	

Figure 2 A *Coursetia glandulosa* A. Gray with *Tachardiella fulgens* present. UAH#89585 and 10354 (KP) Sabino Canyon, Santa Catalina Mtns., Pima Co. AZ. Collected by Kearney & Peebles 9/27/1934. Photo by M. Pool 3/29/2016. **B** Detail from same image.

Figure 3 A *Coursetia glandulosa* A. Gray with *Tachardiella fulgens* present. Collected by M. Pool at Sabino Canyon, Santa Catalina Mtns., Pima County, AZ, 10/11/2015 **B** *Coursetia glandulosa* A. Gray with *Tachardiella fulgens* collected at same location by M. Pool, 3/18/2019.

Table 2: Classification of *Tachardiella larreae* and its primary host plant, *Larrea tridentata* (Barrows 1900:48; Spier 1955:8; Euler & Jones 1956; Mabry 1977; Sutton 1995; Rea 1997:38; Ben-Dov 2006; Moser & Marlett 2010:308; Kondo & Gullan 2011; Bye 2016).

Lac scale species		Primary host plant species
Tachardiella larreae (Comstock)		*Larrea tridentata* (Sessé & Moc. ex DC.) Coville
Order	Hemiptera	Zygophyllales
Suborder	Sternorrhyncha	
Family	Kerriidae	Zygophyllaceae
Superfamily	Coccoidea	
Common Names		
English		Creosote bush, Greasewood
Spanish	Goma Sonora	Gobernadora, Hediondilla
Seri (Comcáac)	Csipx	Haaxat
Pimería Alta, Ópata	Xuarí, Juarí	
Mojave	Axpi'lyà	
Cahuilla	San-ot	
O'odham	Shegoi ushabi	Shegoi

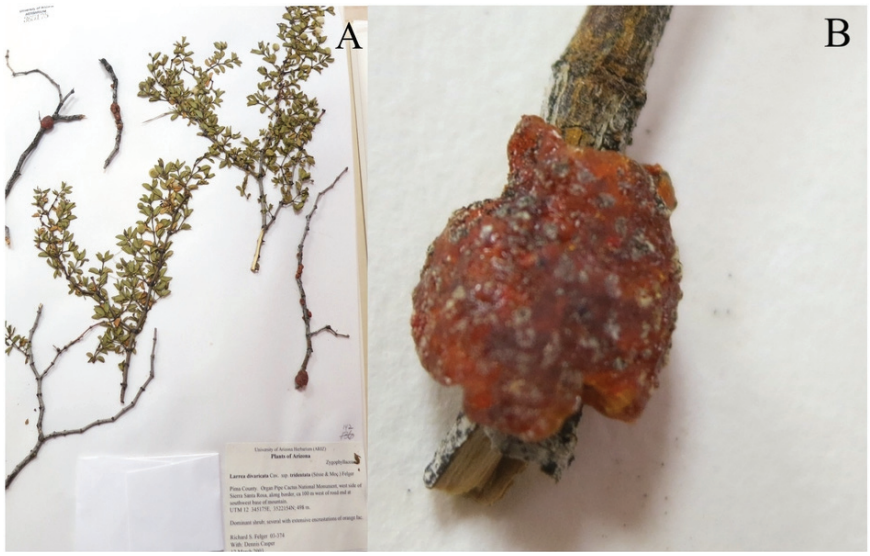

Figure 4 A *Larrea divaricata Cav* spp. *tridentata* (Sesse & Moc) Felger with *Tachardiella larreae* present. UAH#365178 Pima County, Organ Pipe Cactus Monument, west side of Sierra Santa Rosa. Collected by Richard S. Felger with Dennis Casper, 3/12/2003 **B** Detail from image on left.

Figure 5 A *Larrea tridentata* with *Tachardiella larreae* present. Death Valley National Park, CA. Near Mesquite Spring campground and Grapevine Canyon, 2016. Photo courtesy of Chris E. White. **B** *Larrea tridentata* on the Barry Goldwater Range 3/5/2018 by M. Pool.

Table 3: Classification and habitat of *Tachardiella pustulata* and its primary host plant, *Pluchea sericea.* (Euler & Jones 1956; Sutton 1995; Turner et al., 1995; Rea 1997:147; Felger 2000; Ben-Dov 2006; Moser and Marlett 2010:308; Kondo & Gullan 2011).

Lac scale species		Primary host plant species
Tachardiella pustulata (Cockerell)		*Pluchea sericea* (Nutt.) Coville
Order	Hemiptera	Asterales
Suborder	Sternorrhyncha	
Family	Kerriidae	Asteraceae
Superfamily	Coccoidea	
Common Names		
English		Arrowweed
Spanish		Palo cochinilla, Cachanilla
Akimel O'odham		U'us kokomagi

Figure 6 A *Pluchea sericea* (Nuttall) Coville, with *Tachardiella pustulata* present. Rio Sonoyta, ca. 0.5 km south of Cerro El Huerfano. University of Arizona Herbarium #298912. Collected by Richard Felger et. al. 25 October 1992. **B** Detail of same.

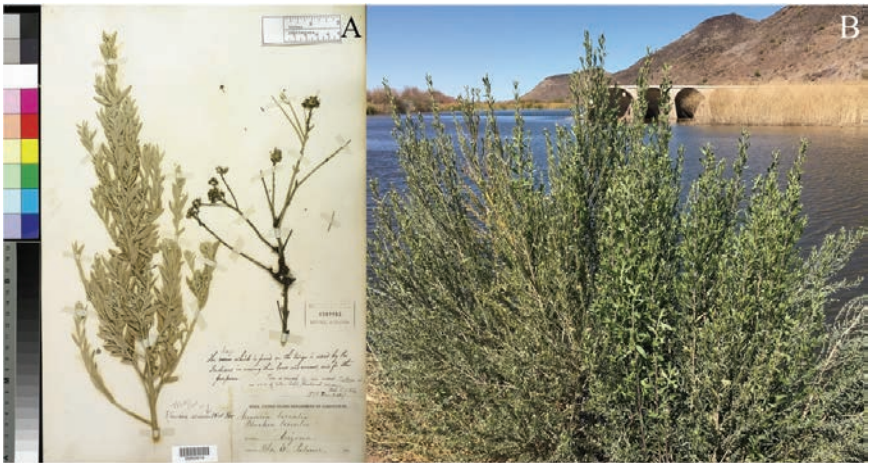

Figure 7 A *Pluchea sericea* with *Tachardiella pustulata*. National Museum of Natural History #93283 Collected by Edward Palmer in Municipio San Luis Rio Colorado, Lerdo, Sonora, Mexico, Dec 21, 1884 – Jan 1, 1885. **B** *Pluchea sericea* growing on shore of Gila River at Old Gillespie Dam Bridge near Arlington, AZ March 4, 2018, by M. Pool.

Table 4: Host plant topography and soil types (Turner et al., 1995; Felger 2000).

Host Plant	Topography	Soil Type
Larrea tridentata	Bajadas, moderate slopes, valley floors, sand dunes, washes	Dry, calcareous, gravelly, sandy, with caliche underlying
Coursetia glandulosa	Rocky slopes, foothills, washes	Dry, rocky, alkaline
Pluchea sericea	Grows along flowing streams, wetlands	Wet, sandy, saline

Preserved specimens of *Tachardiella* spp. with documentation accessed through online networks, listed below, are currently found in the entomological collections of a limited number of institutions, the majority being in California between the CASC and the CSCA (Acronyms summarized in Table 5). Thirty-one specimens are in London at the NHMUK. Collections with approximately five or less specimens are housed in the MCZ, MSU, NMSU, UAEC and the USNM (Table 5).

Table 5: Summary of documented *Tachardiella* spp. specimens by collection type and data sources and list of data sources

Collection type	Data sources	No. of specimens
Entomological	SCAN, iDigBio, GBIF	96
Herbaria specimens with *Tachardiella* present	Herbaria collections online/in person: ASUH, DES, FMNH, NMNH, RSA, SDNH, UAH	16
Tachardiella spp. specimens found in Anthropological collections	Natural History & Anthropological Museum collections online/in person	33
iNaturalist observations	iNaturalist	112
Author and colleague observations	GPS readings	11
Total		268

Acronym	Institution/Organization
ASUH	Arizona State University Vascular Plant Herbarium
CASC	California Academy of Sciences
CDFA	California Department of Food and Agriculture
CSCA	California State Collection of Arthropods
DES	Desert Botanical Garden Herbarium
FMNH	Field Museum of Natural History
GBIF	Global Biodiversity Information Facility
iDigBio	Integrated Digitized Biocollections
iNaturalist	Web based human observations of specimens only
IRHN	Intermountain Region Herbaria Network
MCZ	Museum of Comparative Zoology, Harvard University
MSU	Michigan State University Entomology
NHMUK	Natural History Museum UK
NMSU	New Mexico State University Arthropod Collection
RSA	Rancho Santa Ana Botanic Garden, Pomona College
SCAN	Symbiota Collections of Arthropods Networks
SDNH	San Diego Natural History Museum
UAEC	University of Arizona Entomology Collection
UAH	University of Arizona Herbarium
UCBMH	University of Colorado Boulder Natural History Museum Herbarium
USNM	National Museum of Natural History, Smithsonian (formerly the USNM)

Of the sixteen *Tachardiella* spp. specimens found with herbaria specimens, nine were *T. fulgens,* five were *T. larreae*, and two were *T. pustulata*. Seven of the *T. fulgens* specimens were

found in Mexico and two were found in Arizona. Three of the *T. larreae* were found in Arizona and two were found in Mexico. The two *T. pustulata* specimens were found in Mexico.

Less than half of the 96 specimens of *Tachardiella* spp. found in entomology collections represented the three species found in cultural materials. Table 6 provides a list of the different specimens and their general localities. Thirty-three *Tachardiella* spp. specimens were found cataloged within Anthropological collections at the following museums: American Museum of Natural History (AMNH); Arizona State Museum (ASM); National Museum of the American Indian (NMAI); Phoebe Hearst Museum (PHM); Peabody Museum of Archaeology and Ethnology (PMAE); and University of Pennsylvania Museum of Archaeology and Anthropology (UPENN). Two of the specimens were archaeological, 4 were described as botanical, 16 were cataloged as ethnographic and consisted of processed lac removed from the stem, and another 16 were also cataloged as ethnographic but were stick lac, still attached to the stem and unprocessed, which may be considered ethnobiological specimens.

The results from iNaturalist observances are summarized in Table 7. The distribution of *T. larreae*, the largest number of specimens observed, is illustrated by percent per state in Figure 8. Specimens of *T. fulgens* were primarily observed in the Tucson area.

Table 6: Distribution of *Tachardiella* spp. specimens from entomological collections. [unk = unknown collection location].

Species	No. specimens	Country	No. specimens by country	State	No. specimens by state
T. fulgens	11	USA	4	AZ	2
		Mex	2		
		Unk	5		
T. larreae	29	USA	20	AZ	4
				CA	13
		Mex	1		
		Unk	8		
T. pustulata	8	USA	8	CA	5
				AZ	1
				Unk	2
T. cornuta	15	USA	12	NM	8
				TX	2
				Unk	2
		Mex	1		
		Unk	2		
T. glomerella	15	USA	14	CA	9
				NM	1
				NV	3
				Unk	1
		Mex	1		
T. ferrisi	2	USA	2	CA	2
T. mexicana	12	USA	2	CA	2
		Mex	6		
		Unk	4		
Tachardiella spp.	4	USA	3		
		Mex	1		

Table 7: Distribution of observances of *Tachardiella* by species by state and county from the iNaturalist network.

Species	State		County	
Tachardiella ferrisi	CA	2	Riverside	2
Tachardiella fulgens	AZ	8	Pima	8
	Sonora, MX	1		1
Tachardiella larreae	AZ	23	Cochise	6
			Graham	2
			La Paz	2
			Maricopa	1
			Mohave	3
			Pima	6
			Yavapai	3
	CA	49	Imperial	2
			Inyo	1
			Riverside	34
			San Bernadino	11
			San Diego	1
	NV	5	Clark	5
	NM	20	Dona Ana	2
			Grant	5
			Hidalgo	5
			Luna	7
			Otero	1
	TX	4	El Paso	4
Total Observances				112

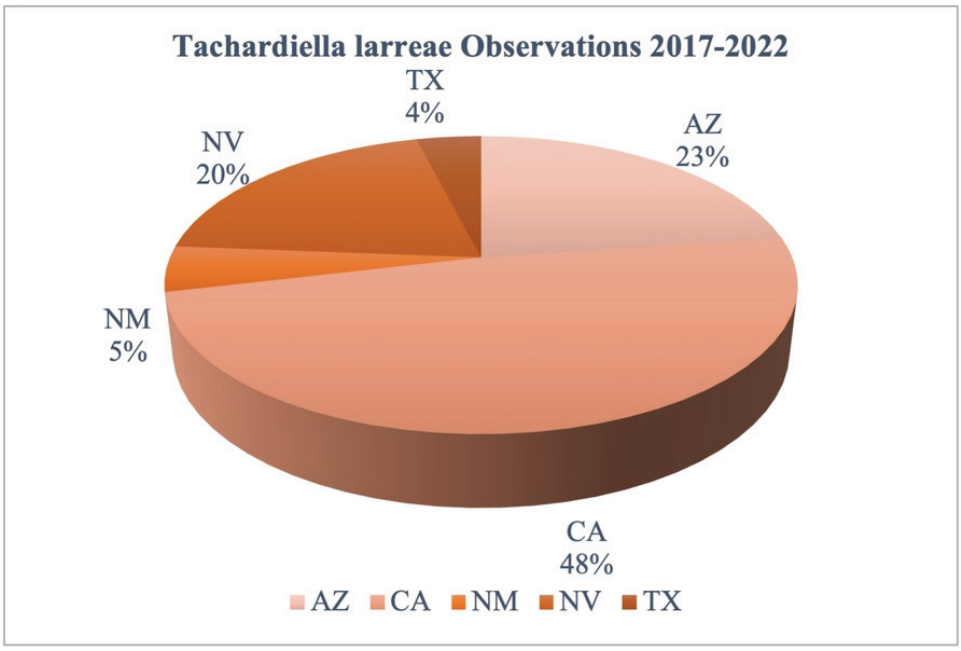

Figure 8 Chart of percent distribution of *T. larreae* by state.

Distribution of *Tachardiella* in maps

Figure 9A is from Colton (1943a), illustrating the distribution of *Tachardiella larreae* determined from the survey he directed the previous year. Colton noted that while there were three species of lac known to live in Arizona (though now we know there are four), his work focused solely on *T. larreae* because his interest was in their abundance and economic value possibilities. Figure 9B shows the distribution of 99 observations made of *T. larreae* by iNaturalist participants. The contemporary map shows observances farther into New Mexico than Colton's but the species' distribution within Arizona is very similar. Colton's map shows more findings in the lower central part of the state where the Tohono O'odham Nation and lands of its people are located today.

Figures 10 through 14 illustrate the distributions of all *Tachardiella* spp. preserved specimens in institutional collections and observed specimens through the iNaturalist network.

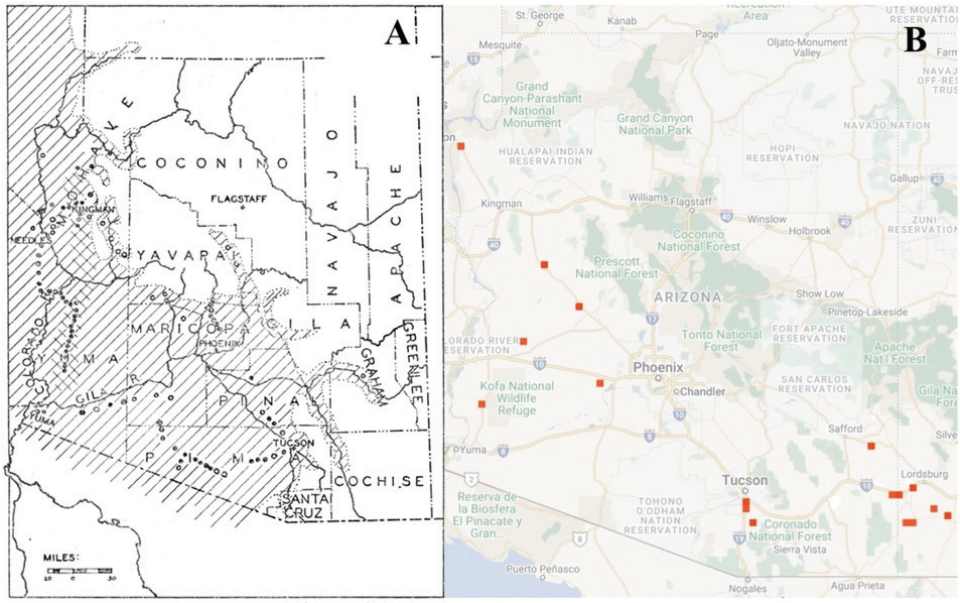

Figure 9 A Distribution of *T. larreae* in Arizona in 1942. The hatched area is the distribution of the host plant, *Larrea tridentata* and the black dots depict stations where lac was found (Colton 1943:24). **B** Distribution of *T. larreae* between 2017 – 2022 based on iNaturalist observations.

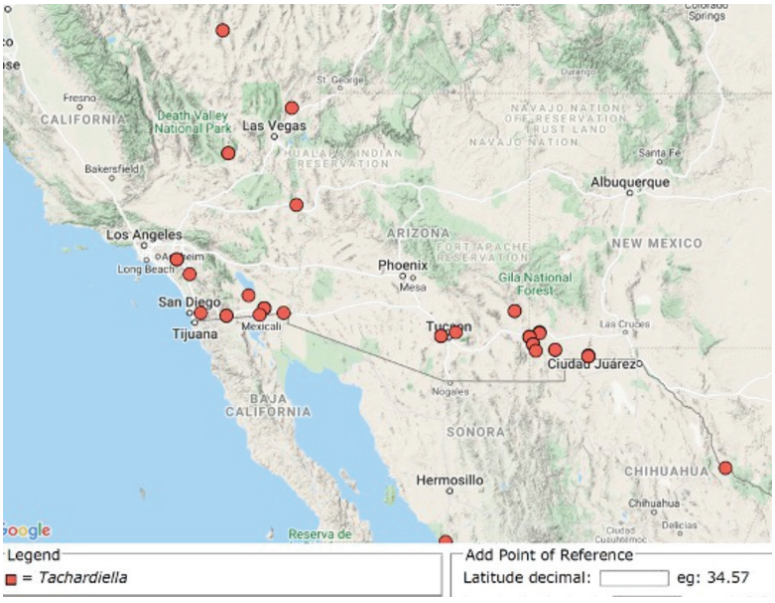

Figure 10 *Tachardiella* spp. collection locations of 76 preserved specimens, Scan-bugs.org, Google map.

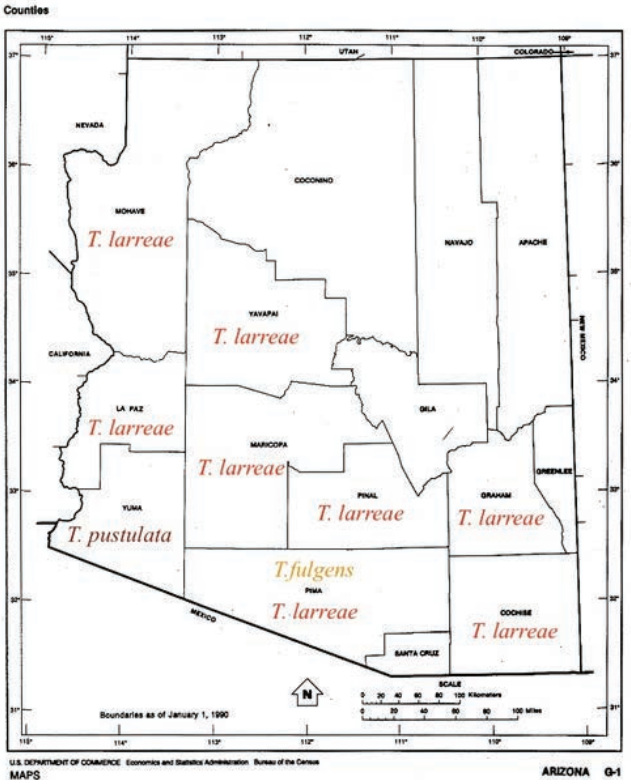

Figure 11 Distribution of *Tachardiella fulgens, T. larreae* and *T. pustulata* by counties in Arizona.

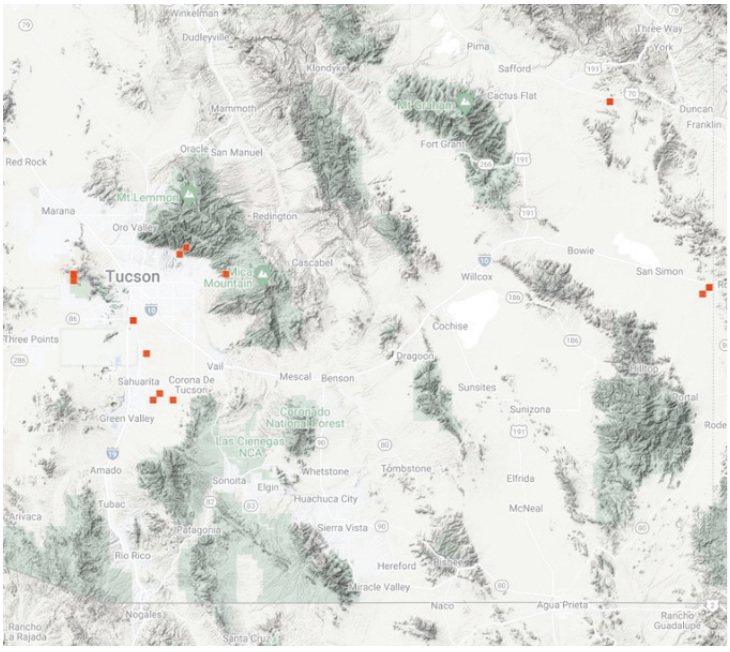

Figure 12 Distribution of *Tachardiella* spp. around southern Arizona from iNaturalist observances. Upper sightings at Kings Canyon and Sabino Canyon are *T. fulgens.* Lower sightings south of I-10 and eastern sightings near New Mexico border are *T. larreae.*

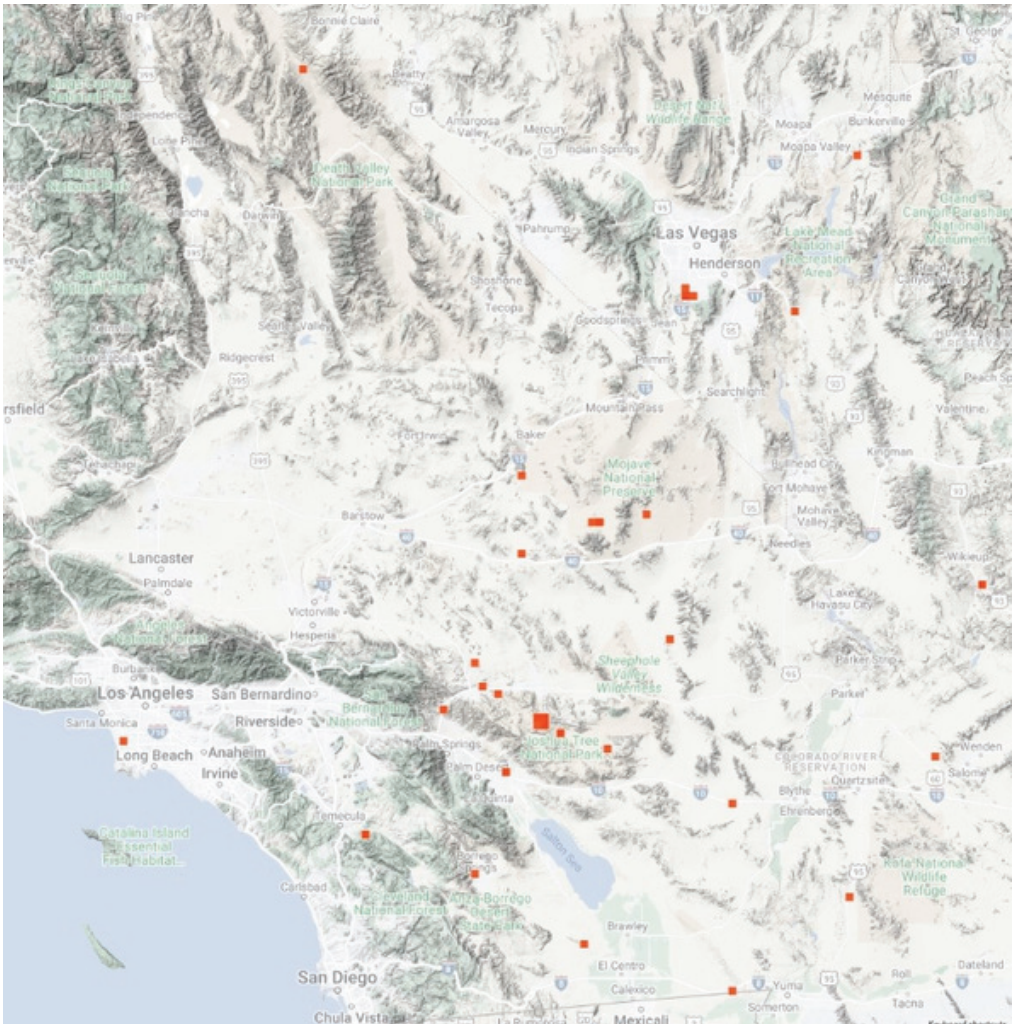

Figure 13 Distribution of *Tachardiella* spp. around southern California and Nevada from iNaturalist observances.

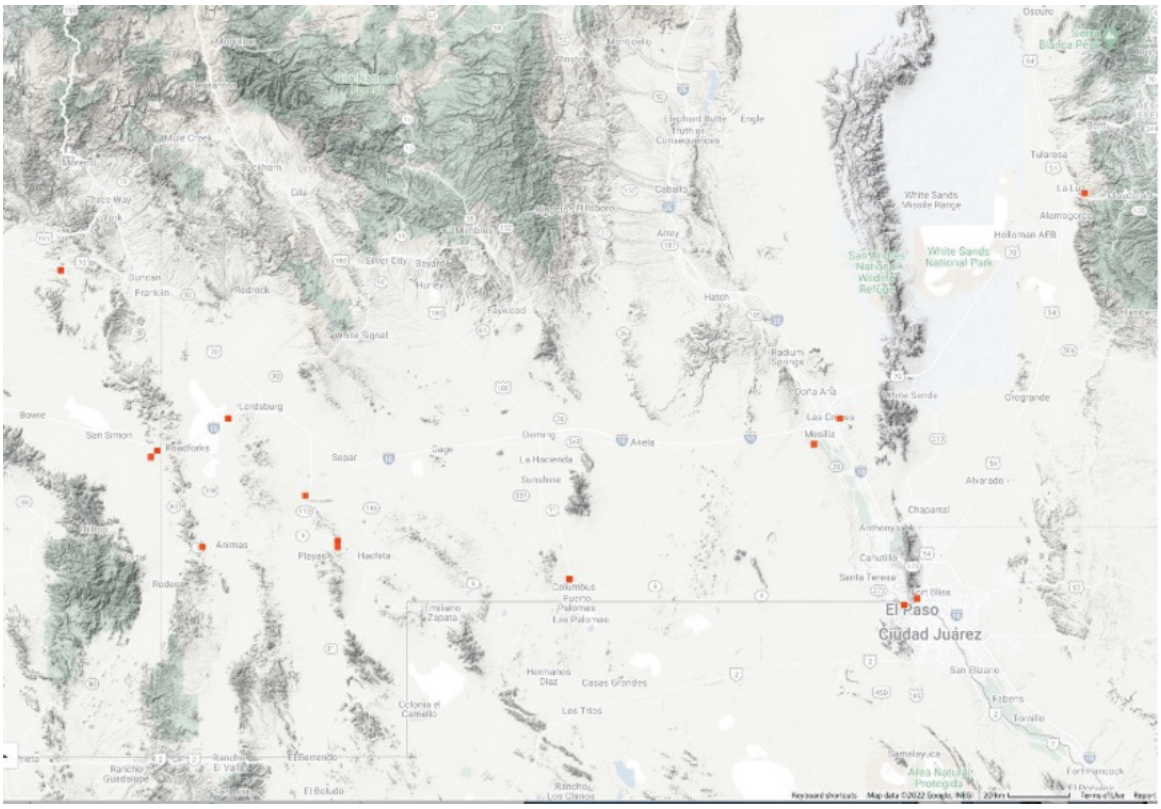

Figure 14 Distribution of *Tachardiella* spp. around southern New Mexico and west Texas from iNaturalist observances.

The combined preserved specimens in non-anthropological institutional collections and iNaturalist observations indicate the following geographical distributions for the three species used in cultural materials:

T. fulgens	USA: Arizona Mexico: Sonora and Chihuahua
T. larreae	USA: Arizona, California, Nevada, New Mexico, Texas Mexico: Sonora
T. pustulata	USA: Arizona, California Mexico: Sonora

The specimens of *Tachardiella* spp. found in anthropological collections revealed an additional source location not seen in the biological collections. *T. larreae* was collected in

southern Utah by John Wesley Powell during one of his expeditions of the Colorado River and Grand Canyon in the early 1870s. Other examples of *Tachardiella* spp. have since been found as parts of artifacts from Utah and Nevada in museum collections, which will be discussed in detail in Chapter 3. This revelation about the Utah and Nevada being home to some *Tachardiella* spp. has changed my initial understanding of lac scale distribution and consequently part of the original hypothesis of this research. At the outset, I understood that *Tachardiella* spp. lived in the lower deserts of the Southwest and its presence in artifacts found North of the Mogollon Rim would likely be due to trade from the South. Finding out the distribution of the insect is much farther north has changed my understanding of possible trade routes used to move lac through the region.

Host Plant Distribution

It is useful to describe the distribution of the primary host plants for the three species of *Tachardiella* to fill in some of the gaps resulting from the limited number of known collected specimens and human observations. This is especially important for *T. pustulata* which is least represented in collections and human observations even though its use is documented in the anthropological literature and is found in anthropological collections.

While the host plants discussed in this research is focused on single species as the primary host, several other host plants have been reported for each species. Some plants, such as *Adenostoma fasciculatum*, in the Roseaceae family, has been found to be a host plant for more than one species of *Tachardiella.* This plant is commonly called greasewood or chamise and has been found as a host for both *T. glomerella* and *T. pustulata* in California. In Arizona, the host plant for *T. pustulata* is *Pluchea sericea* (Kondo and Gullan 2011). Other host plants reported for *T. fulgens* include two other plants in the Fabaceae family, *Coursetia axillaris* and *Sesbania.*

Herbarium specimens were located using Seinet, iDigBio, and the Intermountain Region Herbarium Network (IRHN) to find distribution data for herbarium specimens and iNaturalist for distribution data from human observations for each host plant species (Figures 15 through 20). As one might expect, the numbers of specimens and observations were much higher than those for *Tachardiella* spp. The data is summarized in Table 8.

Table 8: Host plant specimens and observances.

Host plant scientific name	Preserved specimens (iDigBio)	Preserved specimens (IRHN)	Observations (iNaturalist)	Locations: Country, States
Coursetia glandulosa	1140	538	393	USA: AZ Mexico: Baja California, Chihuahua, Colima, Durango, Guanajuato, Guerrero, Jalisco, La Paz, Nayarit, Oaxaca, Queretaro, Sinaloa, Sonora, Tamaulipas, Yucatan, Zacatecas
Larrea tridentata	4561	6528	53897	USA: AZ, CA, NV, NM, TX, UT Mexico: Baja California, Chihuahua, Coahuila, Durango, Guanajuato, Hidalgo, Nuevo Leon, San Luis Potosi, Sinaloa, Sonora, Zacatecas
Pluchea sericea	1210	1422	2433	USA: AZ, CA, NV, NM, TX, UT Mexico: Baja California, Chihuahua, Sonora

Of the two hundred and thirteen *Coursetia glandulosa* observances in Arizona, one hundred and ninety-three, or 90%, were in Pima County. Baja California, Sinaloa and Sonora had the most observances in Mexico.

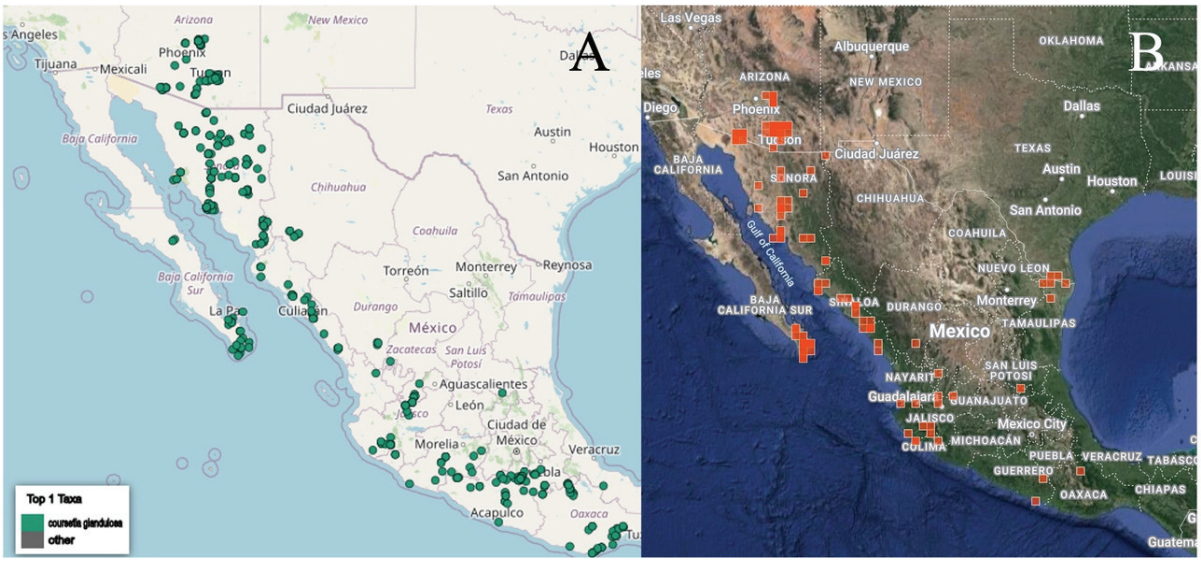

Figure 15 A Map of distribution of iDigBio specimens *C. glandulosa* **B** Map of distribution of iNaturalist observances *C. glandulosa*.

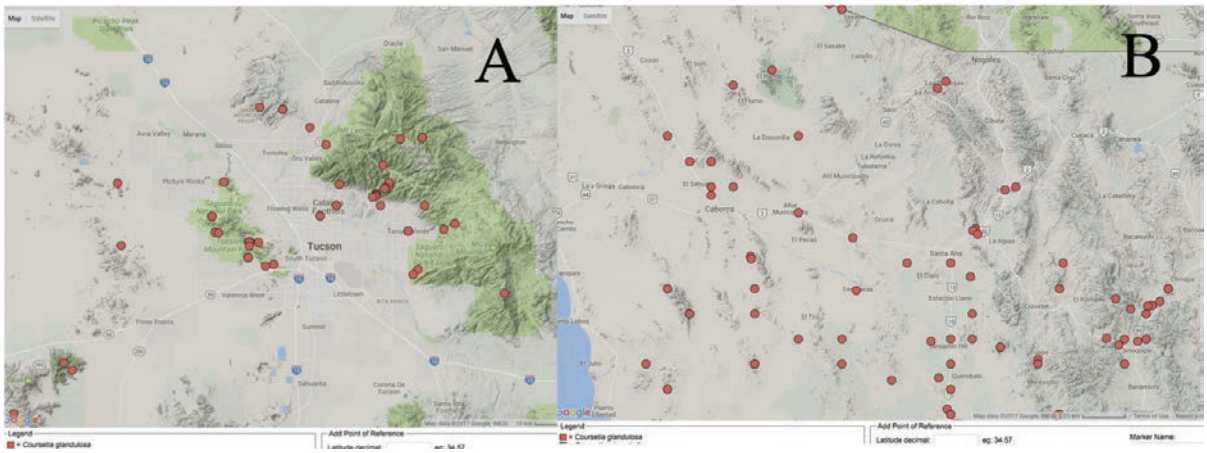

Figure 16 A Map of distribution of IRHN specimens of *C. glandulosa* in Tucson area **B** Map of distribution of IRHN specimens of *C. glandulosa* in Northwest Sonora.

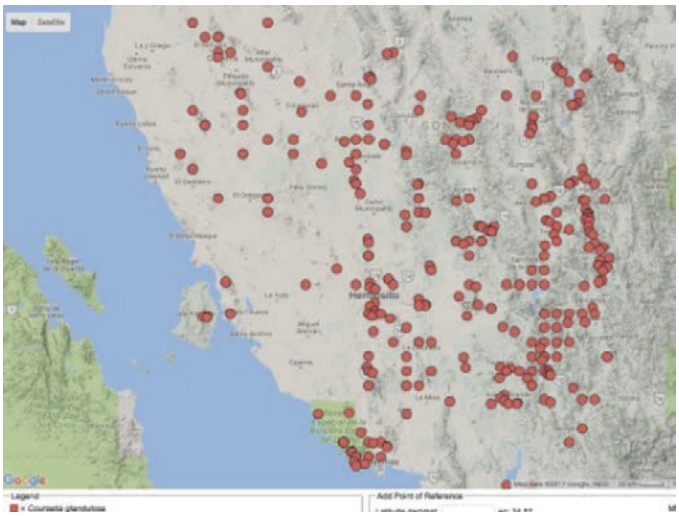

Figure 17 Map of distribution of IRHN specimens of *C. glandulosa* Central and Western Sonora.

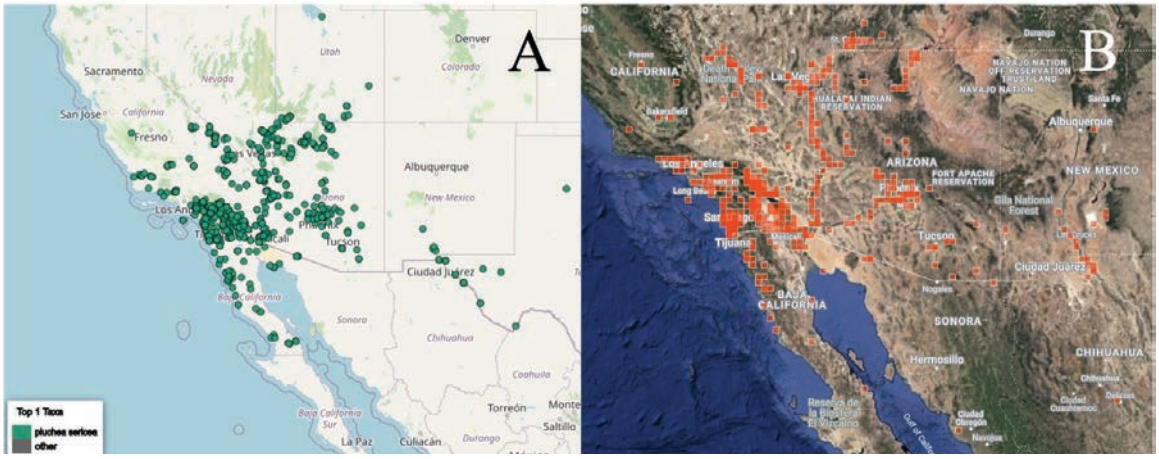

Figure 18 A Map of distribution of iDigBio specimens of *P. sericea* **B** Map of distribution of iNaturalist observances *P. sericea.*

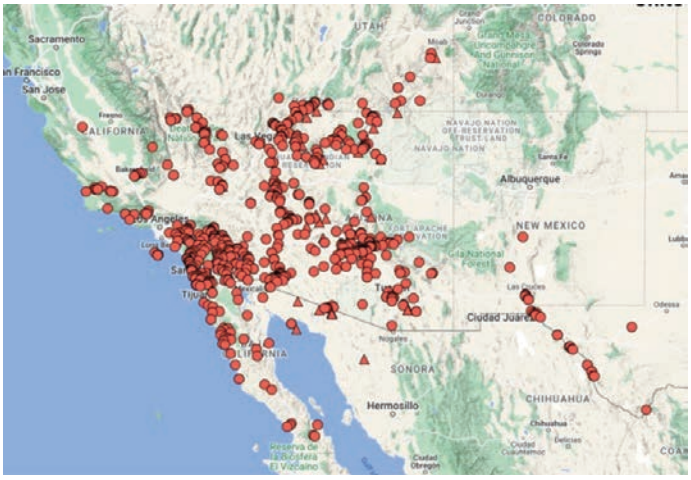

Figure 19 Map of distribution of IRHN specimens of *P. sericea.*

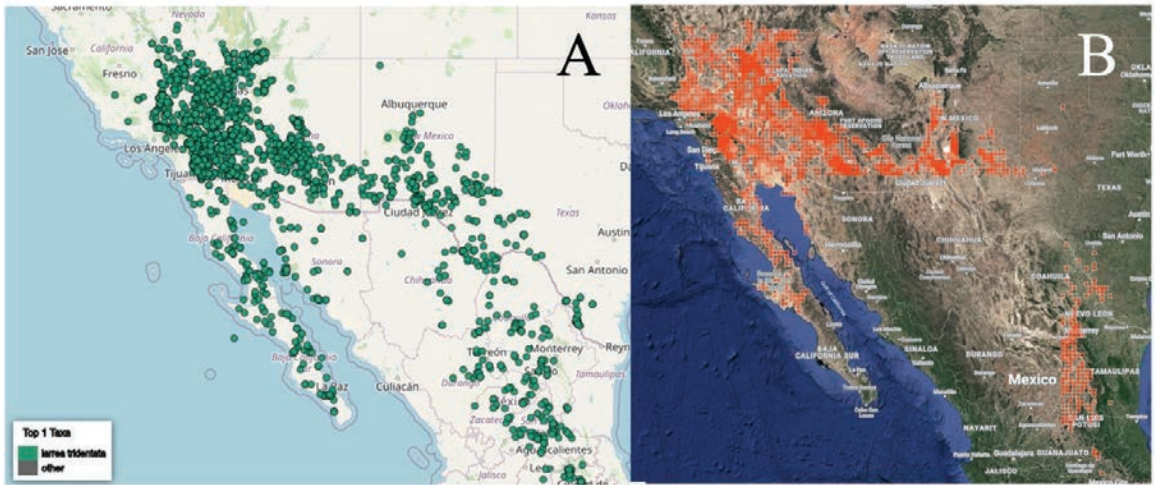

Figure 20 A Map of distribution of iDigBio specimens of *L. tridentata* **B.** Map of distribution of iNaturalist observances *L. tridentata.*

Conclusion

Given the large difference in numbers of specimens collected and observed between the primary host plants and the three species of *Tachardiella,* the resulting known distribution of host plants is far broader and denser than the insects. The host plant distribution can inform and expand the possible *Tachardiella* spp. distributional boundaries, especially when examining the collection locations of museum artifacts that contain insect lac in their material components. As will be discussed next in Chapter 3, many of the collectors of herbaria and entomological specimens containing lac also collected artifacts with lac components, thus expanding the known range of some *Tachardiella* species.

The distribution of *Tachardiella fulgens* is in the Sonoran and Chihuahuan deserts. It is found in Arizona, and the states of Sonora and Chihuahua, Mexico. The distribution range of *Coursetia glandulosa* extends farther into southern and eastern Mexico and *Tachardiella* spp. have not been found in those more tropical habitats. *Llavein axin*, a non-lac producing scale, does grow in the Yucatan, Mexico. *Tachardiella fulgens* tends to appear on the primary host

plant wherever they are found, though on selected clusters of plants, not on most plants in a ravine community.

The distribution of *T. larreae* is in the Mojave, Sonoran, Chihuahuan deserts. It is found in southern Arizona, southern California, southern Nevada, southwestern New Mexico, northwestern Texas, and southwestern Utah. *Larrea tridentata* has the same range in the United States as *T. larreae* but is far more widespread in population numbers than the insects. Like *Coursetia glandulosa*, the host plant range extends farther into Mexico than *T. larreae.* Unlike *T. fulgens*, *T. larreae* appears to be more selective about the environmental conditions in which it will grow, since vast populations of *Larrea tridentata* throughout the host plant range are not infested with the lac scale, as shown by Colton's survey and more recent naturalist observations.

The distribution of *T. pustulata* is in the Mojave and Sonoran deserts. It is found in Arizona, southern California, potentially southern Nevada, and southern Utah and Sonora, Mexico. *Pluchea sericea* also has a wider range than *T. pustulata*, though artifact research has expanded those boundaries into Nevada and Utah.

CHAPTER 3

Archaeological cultural use of lac scale (*Tachardiella* spp.*)* documented in anthropological literature and in artifacts found in selected museum and repository collections

Introduction

People have been using adhesives as repair materials and for fabricating objects for approximately two hundred thousand years (Langejans et al., 2022). Neanderthals used a tar glue byproduct of birch bark to haft tools, and people of Medieval England possibly used the same tar for coatings (Niekus et al., 2019; Stacey et al., 2020). People in Middle Stone age Africa used plant gums and ochres for adhesives (Kozowyk et al., 2020). Other common adhesives in the ancient world included bitumen and asphalt, animal skin based collagen, beeswax and adhesives from a variety of plants and minerals (Fay 2021; Langejans et al., 2022). In Mesoamerican civilizations, adhesive sources included pine pitch and copal tree resins, beeswax, bitumen, and rubber latex (Wendt and Cyphers 2008; Stacey and Cartwright 2009). Finally, lac scale exudates, which are the focus of this study, have been prominently employed as dyes, coatings, and adhesives for millennia.

The cultural use of lac extends back many thousands of years in Asia. Called *Laksha* in India, meaning one hundred thousand, for the multitudes of newly hatched lac scales, it is mentioned in early texts in the Vedic period, 2500 to 1500 B.C. as a medicinal and for charms (Hora 1952). The ancient Chinese employed lac dye for textiles, as did ancient Greeks and Romans, who acquired it from India (Ghorai 1995). A Dutch merchant and traveler, Jan Huyghen van Linschoten, wrote about lac produced in Burma for wood varnishing in 1596 (Gibson 1942). Lac dye from Asia became an important commodity in Europe via the British

East India Company in the 17th century as a less expensive alternative to cochineal dye (Gibson 1942).

In the arid Southwest, people have used the exudate from lac scale insects in the region's cultural traditions from the prehistoric into the historic eras. This material was used as an adhesive in the construction of arrows, jewelry and mosaics (Gladwin et al., 1937; McGregor 1943), as a sealant of pottery jars for food storage (Euler and Jones 1956; Sutton 1995), as a resist for shell etching (Gladwin et al., 1937), for the manufacture of handles for awls, knives and other wooden tools (McGregor 1943; Haury 1950), and for the repair of pottery (Haury 1950; Fontana et al., 1962). This chapter will describe in detail these cultural uses of insect lac in the region as documented in anthropological and other literature and in the manufacture of archaeological artifacts and other objects found in selected museum and repository collections.

One of the major challenges in using museum collections for research is poor and inconsistent documentation, including a complete lack of documentation in museum records, or perhaps worse, misinformed documentation regarding affiliation, materials, technology, and provenience. Miller (2020) states that museum objects are tangible tools to prove a truth of a subject. As evidence, the objects in collections must be honestly described and portrayed, their authenticity central to ethical museum collections policies. Scholarship and analysis of museum collections can provide clarity and correction of poor quality museum records from the past.

When there is misinformation in the documentation the assumptions made about the material identity, cultural affiliation or species can be repeated in multiple publications (Fox and Sutton 1995:363). For example, multiple scholars used generic terms for resins found on artifacts calling them gum, which is not a resin at all. There was confusion between plant and insect exudates, as well as confusion over insect exudates between true lac produced by *Tachardiella*

spp. and a wax-producing scale in Mexico called *Llavein axin.* Furthermore, the nomenclature and systematics changed throughout the twentieth century for lac scale species and also their host plants (as described in Chapter 1).

The first known description of cultural use of *Tachardiella* spp. in the Americas was found in letters written home by a Swiss Jesuit Missionary stationed in Sonora, Mexico in the eighteenth century. Phillipp Segesser wrote to his family in January 1730 about a material called *Goma de Sonora.* He described it as coming from a plant, not knowing its source was an insect. He said the indigenous people used it medicinally to treat poisons (Thompson 2014). A German missionary, Ignaz Pfefferkorn, wrote of *Gomilla de Sonora* which he learned was a remedy for hemorrhages and treatment for rabies from his stations in the village Ati and Guevavi starting in the 1750s (Pfefferkorn 1989). Another German priest who served with the Opata and Pimans in Sonora and Arizona in the mid 1750s, named Juan Bautista Nentvig, reported that *Goma de Sonora* was a remedy for insect stings (Nentvig 1980). In 1876 a report about *Goma de Sonora* or Arre (*arí*) was published in the journal *New Remedies*. Samples had been sent to Germany for chemical analysis. The anonymous author of the report stated that Mexicans in antiquity called it *Tzinacancuitlatl* and that it was produced by a coccus shellac like insect and produced a red cochineal like color, all astute observations. The author also noted it was used by contemporary Mexican people for inflammation and respiratory problems (New Remedies 1876).

In an 1874 botanical dictionary under the entry for Larrea, it is noted that the Pima (Akimel O'odham) Indians used the resin from the plant to treat rheumatism and to make into balls for kicking while on trails (Lindley and Moore 1874). The resin of *Larrea tridentata* is known to have many medicinal applications, but the coating for kicking balls could only be *Tachardiella larreae*, the insect lac associated with the plant. Many years later *Goma de Sonora*

was mentioned as a medicinal still used by the Yaqui people living in Sonora, Mexico where it was boiled in water and mixed with cinnamon, mint and anis seed to treat diarrhea (Holden et al., 1936). According to Bye (2016), national and international trade of *Goma de Sonora* ended after the expulsion of Jesuits in 1767. However, *Goma de Sonora* can still be found in markets selling medicinal herbs in both Chihuahua (where it is sold as *arí*) and southern Sonora, Mexico. Before the 20th century, medicinal lac was used primarily to treat bites, stings, and poisons. From the 20th century forward, it has been used to treat gastrointestinal disorders and hangovers (Bye 2016).

Problems with terminology and nomenclature

Gum was the most frequent term used to describe lac exudate into the 1900s as shown in Table 9 below. In some instances, the collector included the proper host plant such as *Larrea Mexicana* (*Larrea tridentata*) and still called the exudate a gum believing the material to be exuded by the plant. In handwritten museum records, Carl Lumholtz noted it was from the *Carteria* scale insect and Mary Kissell specified it was from the *Carteria larreae* insect. Both were collecting for the AMNH in the same year. *Carteria larreae*, as mentioned in Chapter 2, was the name published by Comstock in 1882. The changing scientific nomenclature for the insects and their host plants over time has added to the confusion of collectors and catalogers. For example, *Larrea tridentata* was previously called *L. mexicana* and *Covillea tridentata*, *Pluchea sericea* was previously called *P. borealis*, and *Coursetia glandulosa* was previously called *C. microphyllia*.

In addition to various scientific names for the species over the years, there are also a wide variety of common names in various languages (Tables 1-3), some of which are very similar

even when they refer to different species. For example, the common name for *Tachardiella fulgens* used by the Tarahumara people of Chihuahua, Mexico is *Arí* (Bye 2016). Another scale insect that lives in the Yucatan and other more tropical parts of Mexico produces fatty waxes (but not true lac) is called *aje* from the Nahuatl word *axin* (Jenkins 1967). *Aje* is sometimes confused with the Tarahumara-derived word *Ali* or *Ari,* used by the people of Chihuahua to describe scale lac. This can be even more confusing because the products are superficially similar: *Aje* is used to produce Mexican lacquerware called *laca*, or *maque*, the first term related to lacquer. Maque refers to the red paste typically applied as the base color in Mexican lacquerware, the word referring to the sumac tree of the same color (Iturbide 1972).

There are many cultural uses of the scale insect *Llaveia axin* (Margarodidae) in central and southern Mexico among the Mayans and Aztecs (Jenkins 1967). The Mayans call it *Niij* or *Ni-in* and in Spanish it is called *Aje* (Williams and MacVean 1995). The species was described by Standley (1920), including its host plants and methods of manufacture for cultural uses. The female fat bodies are extracted and mixed with chia seed oil, minerals and pigments and applied to substrates in layers with buffing. The fats polymerize with drying to form a durable, waterproof coating for gourds, wood objects and pottery decoration (Suazo-Ortuño et al., 2013). Like cochineal, the *Aje* producing scale *Llaveia axin* was cultivated in Mexico at least back to the 1600s and on into the 20th century (Holien 1977; MacVean 2004). Adding to the complexity, not all Mexican laca is made with the *Aje* insect fat. Some consist only of the plant oils, minerals, and pigments. Laca made in Guerrero province does not include *Aje*, whereas Michoacan and Chiapas are the primary centers for laca made with *Aje* (Iturbide 1972).

Use of the word ‘pitch’ by anthropologists, collectors, and museum catalogers to describe adhesives becomes more common in the mid-1920s but is often included with ‘gum’ as another

option. The word lac was not used until the 1950s, though gum and pitch were in continued use as other options. By the 1970s, the word lac was more typically used to describe lac by the collectors, but not as often in museum catalog cards. By the 1980s, lac was more often classified as a resin, which is correct, though generic. Table 9 summarizes the wide variety of terms used by various collectors over the past 150 years. One of the goals of this research has been to assist in correcting vague or mis-documented records from the past, in an attempt to lead lac exudate out of obscurity.

Table 9: Selected collectors of specimens and artifacts of lac through time and the variation in terminology used to describe the material.

Collector	Object Name	Material identified by Collector	Actual Material	Date Collected/ Donated
Powell, J.W.	*Larrea mexicana* twigs and gum	Gum for dye	Insect lac	1874
Palmer, E.	Prepared gum	*Larrea mexicana* gum used to mend pottery	Insect lac	1876
Coville, F.V.	Botanical specimen, Gum of the Larrea mexicana	Gum of *Larrea mexicana*, used as arrow glue	Insect lac, stick lac	1892
McGee, W.J. & Dimwiddle	Arrows	Cement, mesquite gum	Insect lac	1894
Pepper, G.	Scraper, inlaid	Pinyon gum	Insect lac, possible	1897
Russell, F.	Gum, cement	Creosote bush gum	Insect lac	1902
Fewkes, J.W.	Turquoise mosaic	Pitch, tenacious and gum	Insect lac, probable	1904
Dubois, C.	Rattle	Pitch?	Insect lac, probable	1905
Cushing, F.H.	Bracelet, shell	Unidentified by Cushing, Haury calls it black substance, probably pitch	Insect lac, possible	1908
Kissell, M.	Awl, gum	*Carteria larreae* insect	Insect lac	1911

Lumholtz, C.	Greasewood gum, pot mending	Carteria scale insect	Insect lac	1911
Harrington, M.R.	Gum, pitch, resin	Pitch from creosote bush used as glue on arrow points	Insect lac	1925
National Geographic Soc.	Scraper bone, inlaid	Mastic gum or pitch	Insect lac, possible	1927
Davis, E.	Gum, pitch	Root with gum on it from arrowweed, used to fasten handle of gourd rattles	Insect lac	1930
Jackson, E.	Mosaic, turquoise	Gum, pitch, or lac	Insect lac, probable	1930
Spier, L.	Gourds for storage	Gum from arrowweed	Insect lac	1930
Spier, L.	Gourds for storage	Gum from arrowweed	Insect lac	1930
Kelly, I.T.	Resin	Creosote bush gum	Insect lac	1934
Caywood, L. & Spicer, E.	Mosaic, turquoise	Pinyon gum	Insect lac, possible	1939
Cummings, B.	Mosaic, turquoise	Pine or juniper pitch mixed with clay	Insect lac	1940
Haury, E.	Gum covered sticks	Botanical material	Insect lac	1950
Michelsen, R.	Figure, ironwood	Lac fill	Insect lac	1960
Schroeder, A.H.	Mosaic, turquoise	Lac, an insect secretion from creosote bush	Insect lac	1961
Bye, Robert	*Coursetia glandulosa* (botanical specimen)	*Coursetia glandulosa* and Lac, *Samo, Ari, Gomilla, Goma*	Insect lac	1972
Rea, A.	*Larrea tridentata*	Lac, *shegoi ushap*	Insect lac	1986
Felger, R.S.	*Pluchea sericea*	*Pluchea sericea* with lac	Insect lac	2003
Marlett, C.M.	Amulet	Insect lac, *csipx*	Insect lac	2019
Moser, M.B.	*Larrea tridentata* with lac	Lac	Insect lac	2019

Material definitions

This section provides proper definitions for some common terms used to describe lac exudate in the past, or materials confused with lac including gum, resin, pitch, bitumen and

asphaltum. A proper definition of insect lac is also provided here. These definitions are based on the chemistry of the material and their sources rather than their physical characteristics. In the past, the characteristics of stickiness, translucence or darkness of color probably had more influence on the choice of term used than the chemistry of the substance.

Gums are water soluble plant exudates composed of carbohydrate polymers, often consisting of polysaccharides. Natural gums are typically produced by woody plants, barks, and seed coatings. Examples of natural gums from the arid Southwest include mesquite gum, *Salvia hispanica* and *Curcurbita* spp. seed starches, and *Opuntia* spp. and *Stenocereus thurberi* cactus mucilage. Gums have been and continue to be used for paint binders, adhesives, and thickening agents (Mills and White 2012; Bisulca, Odegaard and Zimmt 2016, Langejans et al., 2022).

Resins are water insoluble exudates of plant and insects and are composed of hydrocarbons. Plant resins are typically composed of volatile and non-volatile terpenoids and phenolics, all secondary plant chemicals (Langenheim 2003; Langejans et al., 2022). Insect resins are composed primarily of polyesters and waxes. Examples of plant resins used in the arid Southwest include pine pitch, juniper resin, creosote bush resin (*Larrea tridentata*) and brittlebush resin (*Encelia farinosa*). These materials are processed with solvents or heat.

Insect lac is a specific type of resin, and in fact is the only animal-produced resin known to date. Lac has a complex chemistry with the prominent constituents being resin, wax, dye, gluten, and impurities (Sharma et al., 2020). When Colton had the chemistry of *Tachardiella larreae* examined, the chemists found it higher in wax and lower in resin than the Asian species, findings that were confirmed in later studies (Colton 1943b; Stacey et al., 1998).

Shellac is the product made from the exudate of the Asian *Kerria lacca* insect and processed from raw material called stick-lac into seedlac by crushing, washing to remove dye

components and removal of stem wood. After heating it is either formed into buttons for sale or for additional manufacturing processes and into thin sheets and crushed into flakes for varnishes, other coatings, and other materials (Mills and White 2012). The biochemistry of *Kerria lacca* will be described further in Chapter 6.

Lacquer is a varnish applied to a substrate forming a durable surface upon drying. The term has been used to describe shellac from Asia (*Kerria lacca*) Laca from Mexico and Niij from Guatemala (*Llaveia axin*). Another type of lacquer from Japan, known as Urushi, is made of a tree sap without any insect components at all, in addition to synthetic polymers (Mills and White 2012).

Finally, bitumen is a by-product of crude oil. It is composed of complex hydrocarbons and contains elements like calcium, iron, sulfur, and oxygen (Langejans et al., 2022). Bitumen has no inorganic material but is often synonymous with the term asphaltum. Asphaltum or asphalt is composed of bitumen as a binder combined with an inorganic aggregate material (Mills and White 2012). Bitumen found along the California coast had also been used as an adhesive, coating, and sealant by the indigenous peoples of the region, particularly for waterproofing baskets and boats (Brown 2016).

Methods

The research methodology includes documentation of data published in the literature regarding cultural uses of insect lac from prehistoric eras in the arid Southwest. The archaeological perishable artifact collections at the Arizona State Museum were initially examined and analyzed in person for the presence of insect lac from 2014 to 2016 (Bisulca et al., 2017). Additional archaeological artifacts at ASM were examined and analyzed from 2017

through 2022. Included with the data from ASM are results of an earlier project from 2006 and 2008 examining adhesives used in the archaeological pottery collections (White et al., 2009). Collections containing lac in specific archaeological collections at the National Park Service, Western Archaeological Conservation Center in Tucson, AZ and the Amerind Museum in Dragoon, AZ were examined and documented in 2017 and 2019, respectively, providing a model for examination of other collections depending on each institution's restrictions to access. The Arizona State Museum required formal requests for access and sampling, which were sent through a Collections Committee and an Executive Committee for approval. Samples were very small and were analyzed with Fourier Transform Infrared Spectroscopy (FTIR) and microchemical spot tests, to be discussed in detail in Chapter 7.

The National Park Service does not allow sampling of collections. Permission to physically access these collections for examination with UV light was given by the individual Parks from which different collections are curated. These Parks included Fort Bowie National Historic Site, Gila Cliff Dwellings National Monument, Lake Mead National Recreation Area, Navajo National Monument, Petrified Forest National Park, Tonto National Forest, Casa Grande National Monument, and Canyon de Chelly National Monument.

Between 2016 and 2017, I had the opportunity to visit several museums, parks, and national monuments in the region where I was able to examine artifacts on exhibit and speak with museum or Park Service staff. In the case of the Himdag ki Museum on the Tohono O'odham Nation, I was hired to conduct a conservation survey of their collections and facilities and I observed a few objects that likely contained lac while walking through storage areas. At Tuzigoot National Monument, I was the only visitor at the time and the Ranger turned off the lights so that I could examine the cases with UV light. I was able to identify some mosaic

artifacts probably containing lac. In other instances, I examined artifacts with resins without UV that possibly contained lac but needed further analysis for certainty. In some cases, as in the Montezuma Castle National Monument, the exhibit labels identified the resins as lac. Table 10 lists the institutions and dates I visited.

Table 10: Institutions visited in person with anthropological collections on exhibit

Institution	Location	Date visited
Aztec Ruin National Monument	Aztec, NM	August 2016
Casa Grande National Monument	Coolidge, AZ	August 2016
Chaco Canyon National Historical Park	Chaco Canyon, NM	August 2016
Cocopah Museum and Cultural Center	Somerton, AZ	October 2019
Edge of the Cedars State Park Museum	Blanding, UT	July 2017
El Paso Museum of Archaeology	El Paso, TX	May 2017
Heard Museum	Phoenix, AZ	June 2016
Himdag ki: Tohono O'odham Nation Cultural Center	Topawa, AZ	March & July 2017
Mesa Verde National Park	Mesa Verde, CO	August 2016
Montezuma Castle National Monument	Camp Verde, AZ	July 2017
Museum of Northern Arizona	Flagstaff, AZ	July 2017 & August 2022
Navajo National Monument	Shonto, AZ	June 2017
Salmon Ruin Pueblo Museum	Bloomfield, NM	August 2016
Tusayan Pueblo Museum	Grand Canyon Village, AZ	August 2016
Tuzigoot National Monument	Clarkdale, AZ	June 2017

Due to the COVID-19 pandemic further plans to gather data in person had to be altered. Many museums were closed to researchers and visitors, and some of the smaller museums are

still closed to researchers as of the summer of 2022. Fortunately, many of the larger museums located outside of Arizona that I had planned to visit in person have their anthropological collections accessible through online databases with accompanying photographs and other documentation. I was able to examine artifacts online from the following list of museums.

Anthropology museums and collections examined with online databases:

- AMNH American Museum of Nat Hist, NYC
- AMW Autry Museum of the West, Los Angeles, CA
- CAS California Academy of Sciences, San Francisco, CA
- FMNH Field Museum of Anthropology, Chicago, IL
- MNA Museum of Northern Arizona, Flagstaff, AZ
- NHMLA Natural History Museum of Los Angeles, Los Angeles, CA
- NHMU Natural History Museum of Utah, Salt Lake City, Utah
- NMAI National Museum of the American Indian, Wash DC/Suitland, MD
- NMNH National Museum of Natural History, Wash DC/Suitland, MD
- PHM Phoebe Hearst Museum of Anthropology, Berkeley, CA
- PMAE Peabody Museum of Archaeology and Ethnology Harvard, Cambridge MA
- tDAR The Digital Archaeological Record – Perishables Research
- UPENN University of Pennsylvania Museum of Archaeology & Anthro., Philadelphia, PA

In some cases, museums were closed to researchers and did not have databases available online, but selected collections of artifacts containing lac were available for examination in publications. The Museum of Us in San Diego, formerly the San Diego Museum of Man, was such an example. The following list of museums are those that remain inaccessible for research that would be desirable for future study:

- Yoemem Tekia Cultural Center and Museum, Tucson, AZ
- Huhugam Heritage Center, Chandler AZ
- Ak Chin Eco Museum, Maricopa, AZ
- Quechuan Museum, Yuma, AZ
- Eastern California Museum, Independence, CA
- Riverside Metropolitan Museum, Riverside, CA
- Agua Caliente Cultural Museum, Palm Springs CA
- Imperial Valley Desert Museum, Ocotillo, CA
- Chiricahua Desert Museum, Rodeo, NM
- Western New Mexico University Museum, Silver City, NM
- Maxwell Museum of Anthropology Albuquerque, NM

- MIAC Museum of Indian Arts & Culture, Santa Fe, NM
- Museo Regional de la Universidad de Sonora, Hermosillo, Mexico

To be able to organize and track data acquired from online sources, I created tabular forms for each institution. The form for anthropological museums has one sheet for ethnographic collections and a second sheet for archaeological collections. The first column for each sheet contains object names to search including: arrow, amulet, awl, ball, football, gourd, harpoon, knife, mosaic, rattle, scraper. Following the object names are the material types listed including: shell, resin, gum, pitch, lac, lacquer, glue, raw material, medicine, repairs, and mends. The second column listed fifteen cultures to search. For each culture I would search older names and contemporary names, for example Pima and Akimel O'odham. The form for archaeological collections was the same as for ethnographic except for the cultural names, which included: Ancestral Puebloan (Anasazi), Hohokam, Mogollon, Patayan, Salado, Sinagua, and Trincheras. The printed forms allowed for handwritten notes on numbers of objects per culture per museum plus notes on collectors and references found in museum records. When available, photographs of the objects and copies of catalog information, catalog cards, and handwritten register information were copied and pasted into a PowerPoint file forming the master index of objects possibly, probably and certainly containing lac exudate. All of these data were then transferred to an Excel spreadsheet to enable filtering, sorting, tabulation, and other analyses. I created a third form that listed the three *Tachardiella* species known to have cultural uses and their associated predominant host plants. Many of the older and larger anthropological Museums in the United States are divisions within much larger Museums of Natural History and include both botanical and entomological departments. In several instances, as will be discussed further on, botanical specimens were often cataloged in the anthropology department when the collector also donated

artifact material. This was common at the Smithsonian National Museum, the Harvard Peabody, and the American Museum of Natural History.

Review of literature and artifact collections for cultural use of lac in the prehistoric era

Adhesives used as repair materials and for fabrication of objects dates back approximately two hundred thousand years (Langejans et al., 2022). The following sections describe in detail the cultural uses of lac over time extending from the Archaic up to the historic era, extending across many ancestral cultures in the greater Southwest region. In addition, there are descriptions of known prehistoric trade in the region of objects containing lac.

Archaic and Basketmaker

In 1975, Jesse Jennings and his crew from the University of Utah Department of Anthropology excavated Cowboy Cave, a site west of the Canyonlands National Monument in Wayne County, Utah. Some of the artifacts they collected are available for viewing on the Natural History Museum of Utah's website. Two objects, a projectile point with resin at the base and a bone gaming piece with resin inlay in indentations strongly resemble lac in the catalog photographs. According to Jennings et al. (1980:33) the points with visible resin all date to the Gypsum Era of Late Archaic. The date range for the Late Archaic for this site was later confirmed to be between 2200 – 1500 BCE (Schroedl and Coulam 1994:23). The authors described all resins found at Cowboy Cave as pitch. In discussion of the use of pinyon pine and pitch at the site, Hewitt noted that pinyon pine pitch was not used at the site prior to 3500 BP (Jennings et al., 1980:135). These dates would indicate that Late Archaic projectile resins at Cowboy Cave predated the use of pitch, supporting the suggestion that the resin could be insect lac exudate instead. The black material visible in the gaming piece, which dates to the Terminal

Archaic period (100-650 CE) could also be insect lac, like others examined from the Basketmaker period elsewhere. If the use of lac could be confirmed in these Archaic era objects, it would be the oldest instance of lac use in the arid Southwest known to date.

A Basketmaker III knife from Broken Flute Cave in the Prayer Rock District in Northeastern Arizona is made of an ungulate bone handle with a pink chalcedony blade hafted to the handle with an orange red colored resin that fluoresced bright orange under UV light indicating insect lac. Sinew is wound around the handle and blade to secure it. Elizabeth Morris published a photo and description of the knife in her 1959 dissertation at the University of Arizona, which was reprinted by the University of Arizona Press (Morris 1980). According to ASM catalog records the knife dates between 354-652 CE, making it another of the oldest surviving artifacts likely to contain American insect lac intact.

Byron Cummings, a former President of the University of Arizona, Director of the Arizona State Museum, and head of the Anthropology Department, explored sites and collected Ancestral Puebloan era artifacts in the late teens and early 1920s in Northeastern Arizona and Northern Utah. Some of the archaeological artifacts he collected contained insect lac according to analysis (Bisulca et al., 2017). The sites where these artifacts were found include Chilchintaboko in Nitsie Canyon, Dome Cave in Navajo Canyon, and Scaffold House in Tsegi Canyon. Unfortunately, Cummings did not publish reports from those excavations and his catalog records are sparse. Alfred V. Kidder and Samuel J. Guernsey of Harvard excavated Basketmaker sites in the same region in the same period as Cummings and did publish their reports in detail (Kidder and Guernsey 1919; Guernsey 1931). The two sets of bone dice Cummings collected from Dome Cave had insect lac coatings and inlay on one side. As illustrated in Figure 22, the bone dice collected by Cummings in Dome Cave are similar in

appearance to those collected by Kidder and Guernsey in Kinboko Canyon with dark brown adhesive coatings and inlay on one side. Kidder and Guernsey (1919:189-190) described the Basketmaker dice as being heavily coated with pitch.

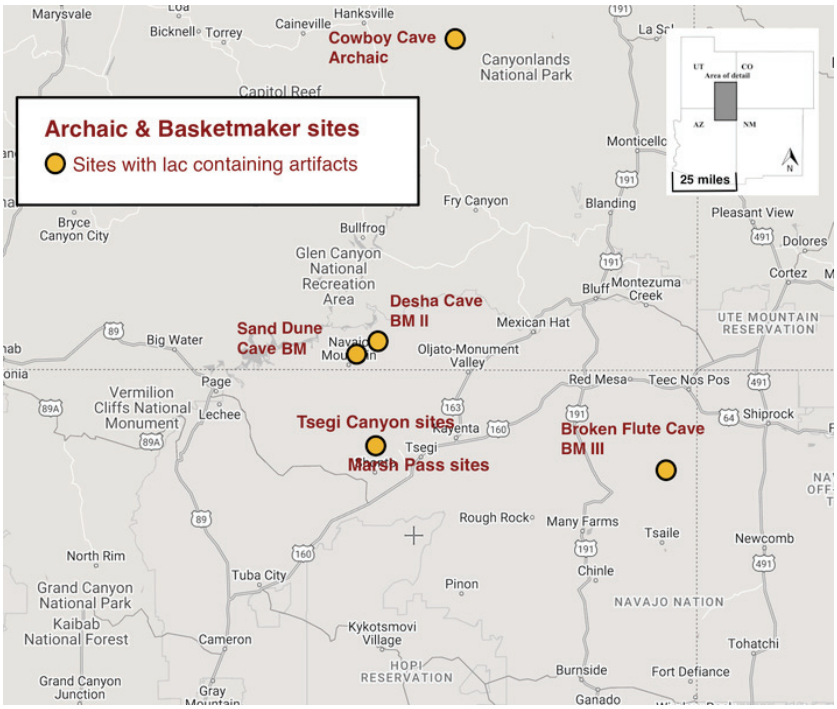

Figure 21 Map of Archaic and Basketmaker sites with lac containing artifacts

Figure 22 A Oblong dice from Dome Cave with lac side showing, ASM#6546-X **B** Round dice from Dome Cave with lac and non-lac sides showing ASM#6547-X Both sets of dice are Ancestral Puebloan, Kayenta Province. **C** Oblong and round dice from Basketmaker site, Cave 1 in Kinboko Canyon, Marsh Pass, PMAE#15-11-10/A2133.

Guernsey described a set of oblong and round dice found in 1923 in the Pueblo III Poncho House site in the Chinle Valley, San Juan County, Utah as having a cement like substance adhering to it (Guernsey 1931:104). Guernsey's illustration of the dice (1931: Plate 24) all have the dark coated side showing. Guernsey also noted that similar dice had been excavated at Pueblo Bonito at Chaco and at the Tularosa site in Western New Mexico. It is likely these dice sets were all backed with insect lac across a range in time from at least Basketmaker III (500-750 CE) to Pueblo III (1150-1300 CE) and were used across the Ancestral Puebloan area from Northern Arizona, New Mexico and into Utah.

Ancestral Puebloan

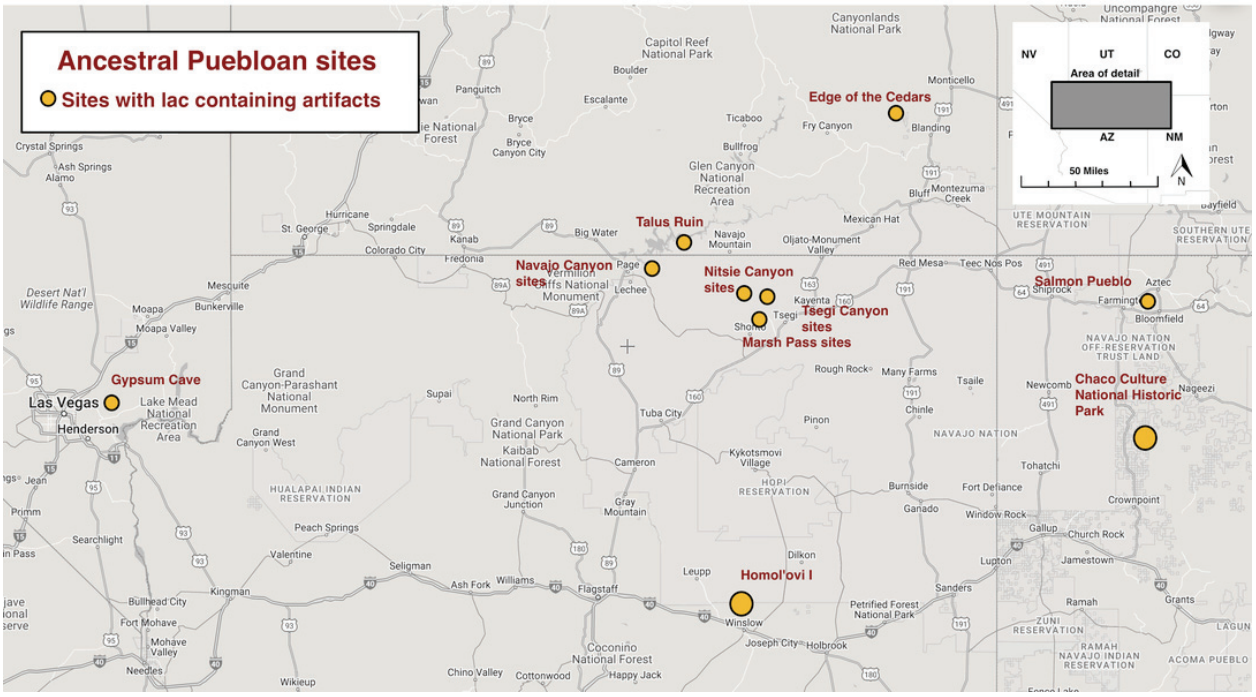

Figure 23 Map of Ancestral Puebloan sites with lac containing artifacts

George H. Pepper published early descriptions of Southwestern Archaeological objects excavated in the region. Pepper and Richard Wetherill were hired to direct the Hyde Expeditions at Pueblo Bonito in Chaco Canyon between 1896 and 1900 in New Mexico, sponsored by the American Museum of Natural History (AMNH). In three of the published papers on the site and its artifacts (1905, 1909, 1920), Pepper used the term gum to describe the adhesive materials found in ornamental objects including turquoise mosaics. Neil M. Judd excavated at Chaco from 1920-1927 and revisited the work by Pepper (Chaco Research Archive, 2021). In Judd's report on Pueblo Bonito (1954) he quotes Pepper's use of the term gum, but himself describes bone scrapers with inlay as being set in pinyon pitch. Insect lac was found to be the inlay material for two of the four scrapers with FTIR analysis, and a third requires analysis but appears to have insect lac mastic from images. The fourth was found to be inconclusive. A turquoise mosaic on shell also was made with insect lac mastic (Bisulca 2019). Earl Morris (1919) described the adhesives for knives as gum and the mastic used for turquoise mosaic as pitch at Aztec Ruin, a Chacoan outlier site in Northern New Mexico.

Jesse L. Nusbaum, photographer, archaeologist, and eventual Superintendent of Mesa Verde National Monument, reported on a 1920 expedition to a Basketmaker cave site in Kane County, Utah. Nusbaum worked for the Heye Foundation Museum of the American Indian at the time. A hafted stone knife was found with a large wad of resin between the blade and handle. The adhesive is described as pitch in the report (Nusbaum et al., 1922:127). On the same expedition, Nusbaum collected a branch of *Larrea tridentata* from the local Kaibab Paiute who described it as a medicine. This specimen is now at the National Museum of American Indian, Smithsonian. Given the illustration of the knife is drawn and not photographed further analysis

would be required to confirm the presence of lac, but the number of hafted knives with documented lac from Southern Utah makes it more likely.

At least three of six Basketmaker II atlatl dart foreshafts are hafted with what appears to be lac exudate under sinew between the stone projectile points and wooden handles. These darts were collected from Desha Canyon, Cave 2 in 1930 by Irwin Hayden and are now in the collections of the Natural History Museum of Los Angeles. The caves are in Southeastern Utah in the Rainbow plateau area just north of the Arizona border. Geib & Robins (2003) provide the history of the excavation of the site along with radiocarbon dates. Geib (2016:49) describes the darts in his dissertation on the topic of fending sticks but does not mention the hafting material on the darts. He does discuss the use of pitch or other plant resin used for the grips on rabbit or fending sticks, however. From the photographs provided by NMHLA, the hafting material does not resemble pitch, especially not the aged pitch shown on rabbit sticks from the similar sites. Instead, it is quite dense and dark like lac. Further analysis would be required to confirm it.

Archaeologists found an Ancestral Puebloan hafted knife during the excavation of Mesa House in Southern Nevada in 1929, which appears to have insect lac as the adhesive in a photograph now in the Autry Museum of the West in Los Angeles. This excavation was directed by Irwin Hayden and included Mark Harrington, by then a Curator at the Southwest Museum in Los Angeles, and Julian Hayden, Irwin's son who was on his first archaeological job, still a teenager. Harrington did not publish details of his archaeological reports from this site, but a University of Arizona graduate student, Richard Shutler, did compile Harrington's field notes and other materials and wrote it up for his dissertation, in which he mentions the discovery of a pendant of lac gum in Chuckwalla Cave near the Lost City site in Southern Nevada, not far from Mesa House. Shutler also describes hafted knives found at Rockshelter 1 near Lost City and

describes them as cemented with pitch (Shutler 1961:112). Harrington excavated another site in Southern Nevada in 1930-1931 called Gypsum Cave, finding atlatl points and a complete dart or knife. Photos of the dart (Harrington 1933:46; Gilreath et al., 2009: Figure 18) show the resin hafting material and it resembles insect lac.

Another site in Utah, Sand Dune Cave, was excavated by Alexander Lindsay and others in 1961 as part of the Museum of Northern Arizona's participation in salvage archaeology in the Glen Canyon Project (Lindsay et al., 1968). The site is located on the Northeast side of Navajo Mountain. In a cache dating to late Basketmaker II, six atlatl darts were found in a bundle. The black and white images in the book are difficult to discern. Lindsay notes they are set with pitch Lindsay et al., 1968:65). In a color photograph of three of the darts taken by a visitor to the Museum of Northern Arizona, the resin resembles insect lac, but further analysis would be required. Seventeen gaming pieces were also found at the site in various assemblages, some round and some oval, all scored and coated with a dark material considered by Lindsay to be pitch (Lindsay et al., 1968:58). The shapes and resin inlay resembles other gaming pieces from the region that contained insect lac exudate.

Sinagua

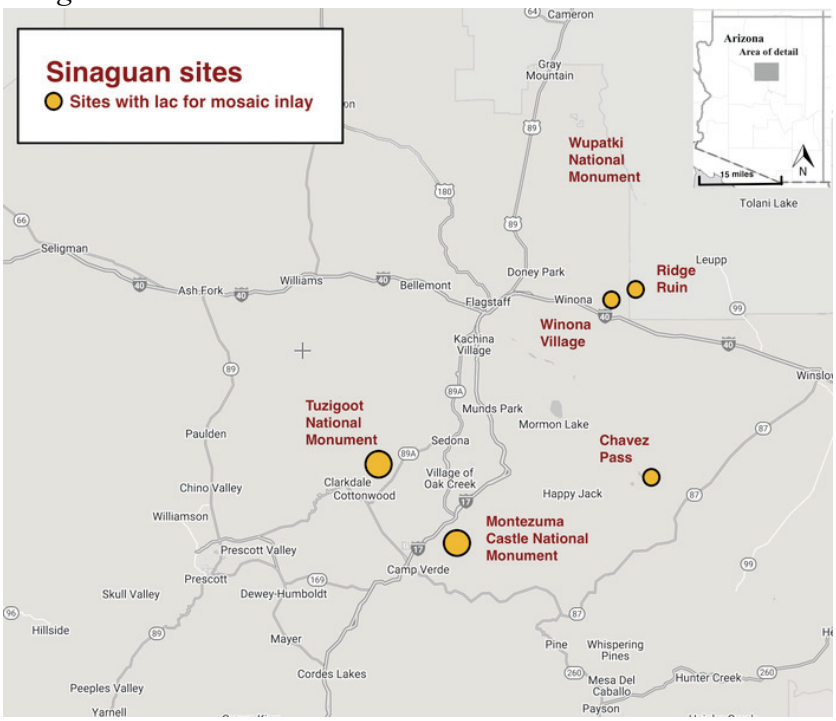

Figure 24 Map of Sinaguan sites in North Central Arizona with turquoise mosaics with insect lac mastic.

The excavations at Ridge Ruin, a Sinaguan site near Flagstaff, provide an example where artifacts found included raw sticklac on creosote bush twigs, partially processed granular lac, simple tools made with lac and prestige objects made with lac as a mastic with a high degree of skill. Colton briefly discusses the site in his article on trade in the Southwest, describing the lac as a plastic material, thinking it may have come from the Lower Colorado River area (Colton 1941:315). McGregor (1943:292) describes these objects in full detail in his report on the Magician, reporting that the lac identified in the artifacts associated with his burial were the first examples of cultural use of lac in North America. McGregor had samples of the material sent for analysis to the botanist Volney Jones in Michigan, who positively identified samples as insect lac using chemical tests and microscopy with known examples from Asia. McGregor offered that the prestige objects could have been made by the Hohokam and traded as manufactured objects,

comparing the mosaics to others excavated farther south in Hohokam territory. He also thought the lac could have been collected from creosote bush in the Salt River Valley or to the west, near Kingman, since the altitude in the Flagstaff area was too high for the range of the creosote (McGregor, 1943:298). It is also possible that the lac came from lower elevation canyon lands farther North in Southeastern Utah or Southwestern Nevada, a potential source area that neither McGregor or Colton had considered at the time.

In the case of Ridge Ruin, the presence of the raw, partially processed, and manufactured objects with lac raises the question whether the prestige objects were manufactured locally by a resident or manufactured by a resident from elsewhere who brought the materials and skills with them. Other prestige objects made with lac have been found preserved in cave sites in Navajo Canyon in the Ancestral Puebloan region, but no archaeological raw materials have yet been found or at least documented and retained (Bisulca et al., 2017:277).

Dr. Charles Adams excavated a mosaic frog ornament from one of the Homol'ovi I ruins, which was identified as having lac as the mastic using FTIR at the Arizona State Museum. Dr. Adams believed the ornament had been made by the Hohokam and brought in as a trade object (Adams, personal communication 2018). The presence of raw material attached to the plant and manufactured objects at Ridge Ruin, or at Ventana Cave farther South (Haury 1950) provides evidence that the manufactured objects were probably locally produced.

Four Sinaguan turquoise mosaics have been examined that contain insect lac exudate as a mastic substrate. The mastic from the mosaic from Chevelon-Chavez Province tested positive for insect lac with FTIR (Bisulca et al., 2017). Another mosaic from Montezuma Castle and two mosaics from Tuzigoot Pueblo were examined while on exhibit, the latter two with UV light. A map of the associated sites is in Figure 24. According to Caywood and Spicer (1935:87) mosaics

from Tuzigoot were made with a gum of pine pitch mixed with clay. Nearly thirty years later, in describing mosaics from Montezuma Castle, Schroeder and Hastings (1961:13) note that the insect secretion, lac found on creosote bush, was sometimes used to adhere the turquoise to shell. Jackson (1954:Figure 44) remarked that the possible adhesive used to secure the turquoise mosaic shaped like a Thunderbird from Montezuma Castle was probably lac, pitch or mesquite gum. Based on the number of Sinaguan mosaics that did contain insect lac, it is likely the Montezuma Castle mosaics did also.

Colton mentioned discovery of *Tachardiella larreae* growing on *Larrea tridentata* in the Verde Valley, proximate to Montezuma Castle during his April 1943 lac survey expedition. His crew also "infested" plants with insects in their survey plot approximately ten miles to the Northwest of Montezuma Castle, not far from the town of Cornville on the way back to Flagstaff (Colton 1943a: April 8-20, 1943, p. 2). Colton's discovery seems to indicate that the Sinaguan mosaics were made locally with a local supply of *Tachardiella larreae* lac for use in mosaics and other artifacts.

Fewkes published an illustration of a mosaic he excavated at Chavez Pass in 1896, shown in Figure 25A below. His description is as follows, "one of the most beautiful examples of mosaic was a worked shell of Pectunculus giganteus covered with turquoise stones embedded in pitch" (Fewkes 1904: 86). Other Mosaic effigies are illustrated below with the other example from Chavez Pass in Figure 26 D.

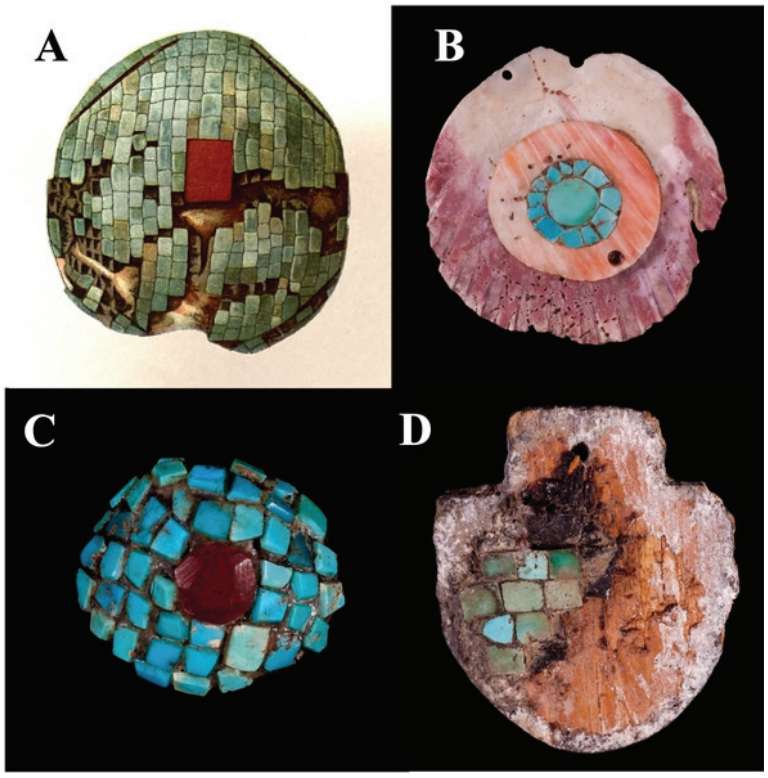

Figure 25 Examples of Sinaguan turquoise mosaics. **A** Illustration of frog effigy from Chavez Pass (Fewkes 1904:Plate XLIV) **B** Shell ornament with mosaic from Tuzigoot (TUZI 133) **C** Turquoise mosaic from Tuzigoot (TUZI 1349) **D** Shell mosaic from Montezuma Castle (MOCA 462).

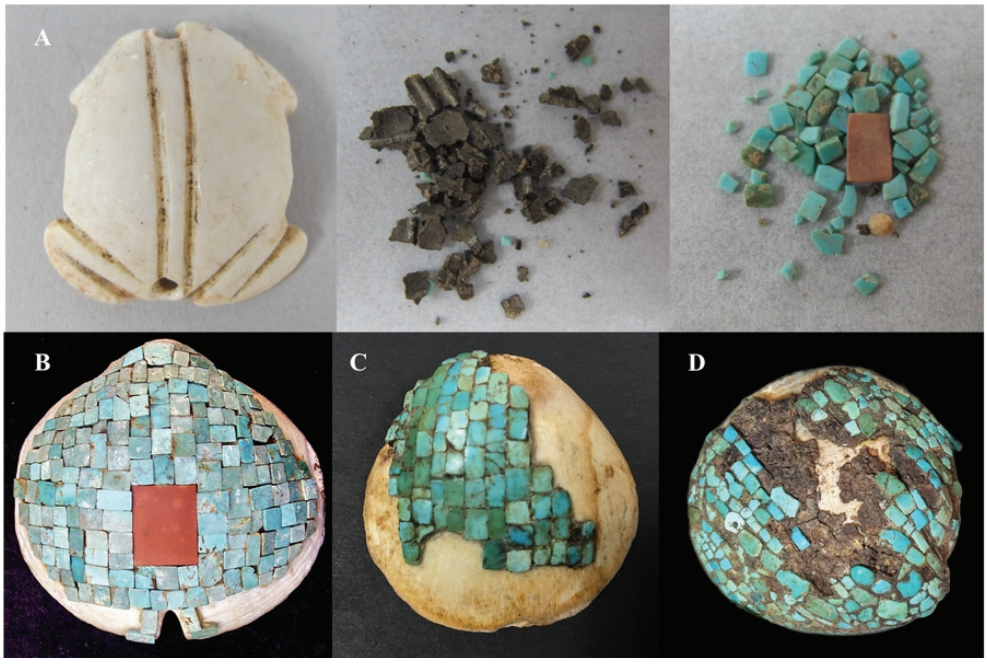

Figure 26 Four effigy mosaics with lac mastic. **A** Homol'ovi I, Ancestral Puebloan, 1285-1400 CE, ASM#2016-31-70. This mosaic was found disassociated as above with shell substrate, insect

lac mastic and stone tesserae **B** Keystone Ruin, Salado – Tonto/Roosevelt 1200-1300 CE, ASM# GP-9895 **C** Kinishba, Mogollon, 1225 -1425 CE, ASM#26365 **D** Chavez Pass Ruin, Sinaguan, 1300-1400 CE, ASM#GP-5765.

Mosaic manufacture

The discovery of lac as the mastic for mosaics across several locations led to questions of how it was technically accomplished. Based on heating tests with freshly collected samples, lac hardens immediately after removing from a heat source and I wondered if there were additives such as clay as some archaeologists suggested (Caywood and Spicer 1935:87; Cummings 1940:61) or perhaps beeswax to soften the material to facilitate the process of inlaying tesserae. I wondered if bone or shell substrates could have been heated also to allow the material to be spread evenly and retain softness.

In correspondence with anthropologist Dr. Mark Sutton, who wrote about the cultural use of lac in the Great Basin (1988, 1990, 1995) I asked if he had any ideas about possible materials or techniques used to apply lac as a mastic for turquoise mosaic. Dr. Sutton replied that he had done his own heating experiments and discovered that quick heating caused the lac to burn and smoke, suggesting slow heating over hours may have been a technique employed for mosaic work.

Hedquist (2017:55) describes mosaics as composite objects, noting that only approximately forty of them have been recovered from Southwestern sites. He discusses a mosaic processing area found within Grasshopper Pueblo with turquoise tesserae in various stages of completion prior to assembly (2017:85). This discovery indicates the mosaics were locally produced at the Mogollon site and not brought in from elsewhere. He also suggests that the tesserae in mosaics found in other sites such as Homol'ovi I, Kinishba, Nuvakwewtaqa (Chavez Pass) may have been processed at Grasshopper, since production areas had not been

found at the other sites (2017:88). Hedquist reported on analysis of the turquoise used in the Homol'ovi I mosaic from (Figure 26A), which found that the turquoise was probably from farther south, in either Southeastern Arizona or Southwestern New Mexico (2017:187). The source of the turquoise is not necessarily the site of manufacture, however. Hedquist's research focused on the stone and pigments used to express social identity and therefore did not address the adhesive substrate or mastic used to manufacture mosaics in any depth. He assumed the mastic was a pine pitch or other similar material and consulted with contemporary a jewelry artist who said pine pitch or perhaps rabbit glue early on was used to apply over the tesserae to secure them (2017:269).

Jernigan (1978) provides illustrations and photographs of several Mogollon mosaics, including frog effigy shapes (Figure 66) and bird shapes (Figure 65) as well as Hohokam (Plate 4) and Sinaguan bird shaped mosaics (Plate 8). Jernigan states that the bird mosaics were manufactured with lac as both the mastic and the substrate, with the bird shaped shell and turquoise tesserae embedded on top of the lac (1978:84). Several of the mosaic pieces in Jernigan's book, as well as in museum collections, are no longer accessible for viewing or analysis due to NAGPRA status and in some cases repatriation, since mosaics were often found in burial contexts. Wilcox (2003:189-193) provides a listing of fifty-eight toad and bird shaped mosaics from the Southwest by site and region, many of which are illustrated by Jacka and Hammack (1975) though without any specific attribution other than culture.

Mogollon

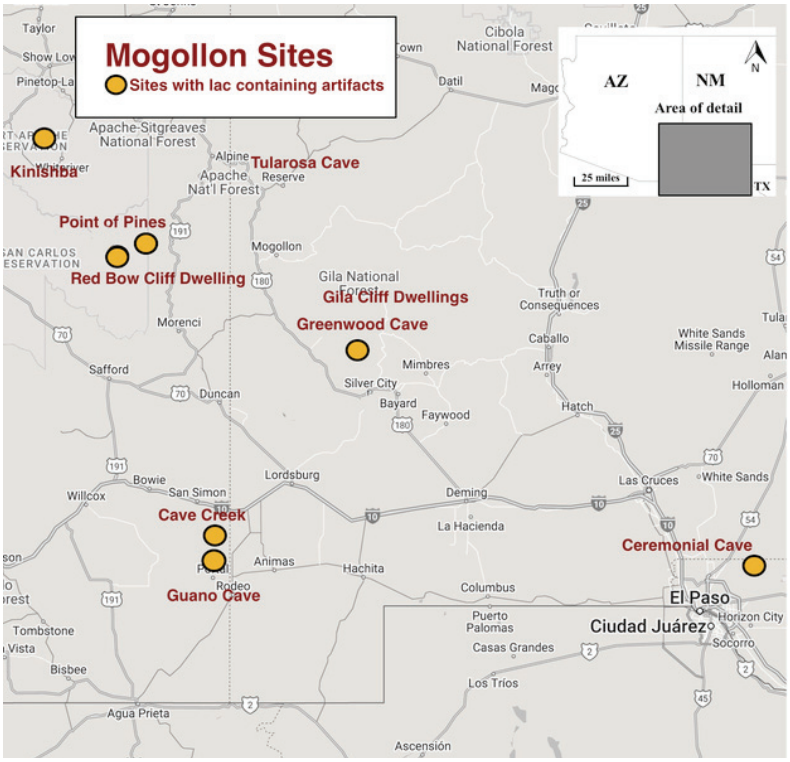

Figure 27 Map of Mogollon sites with lac containing artifacts

Byron Cummings found two turquoise mosaics during the 1933 excavations at the Kinishba Ruins site in White River Province in Arizona. Cummings (1940:61) described the mastic securing the tesserae as being either juniper or pine resin mixed with clay. One of the two, ASM#26365 (Figure 26 C) was identified with analysis as insect lac exudate. The other mosaic, ASM#6748, was observed under UV light only and the results were inconclusive since the mastic was concealed by the completely present tesserae. A Smithsonian ethnologist, Dr. Walter Hough, was sent to survey archaeological sites in the Upper Gila River and White Mountains area between the Arizona and New Mexico border zone in 1905, one of which was Tularosa Cave. He found a skin bag with a collection of round bone dice that he said were "coated with gray mud on one side" (Hough 1914:128). Upon examination of the online catalog record at the NMNH the notation there stated that an adhesive compound was smeared on one side.

Unfortunately, there was no accompanying catalog photograph. The image of the dice in Hough's report does not clarify the adhesive material, but the dice are nearly identical in shape and style to those excavated by Cummings at Dome Cave in the Ancestral Puebloan region (Figure 22B). The adhesive in the Tularosa dice may be insect lac but would require further analysis to be certain. Gifford (1957:196-197) describes gaming pieces or dice from Red Bow Cliff Dwelling as being scored and blackened with charcoal. (ASM#A-17006-X) He notes the similarity to the dice found in Basketmaker and Puebloan sites, such as Pueblo Bonito. Gifford (1957:204) also describes a rectangular pendant of shell with layer of black-brown material resembling pitch, which may be a lac resist (ASM #A-16852). When I asked to examine these pieces with UV light, unfortunately they were not found in their assigned storage location in the Archaeological Non-Perishables collections. Apparently, collections had been relocated and storage locations hadn't yet been updated. Perhaps one day I'll be able to examine them.

Most of the Mogollon artifacts identified through analysis as containing lac are arrow foreshafts from the Point of Pines, San Simon and Chiricahua Provinces. All but the arrow from Cave Creek Village farther south, which dates within the Early Pithouse period (200-500 CE) are dated to the Mogollon Pueblo period (1000 – 1450 CE). As described by Bisulca et al., (2017:279), the arrows from Red Bow Cliff Dwelling near Point of Pines had both insect lac and pine resin as adhesives, according to FTIR analysis. The lac was used to join the point to the foreshaft, and the pitch was used on the tenon joint in compound arrows. To date, the Mogollon are the only ancestral population found to use both adhesives simultaneously on single artifacts, indicating an awareness of the different properties of the materials and their functional applications.

Gifford (1957:94) described the arrow adhesive material only as pitch in his Masters thesis, based on field work in 1955 in the Point of Pines Province. Haury (1934:106) notes that hardwood foreshafts were smeared with pitch before insertion and bound with sinew at Canyon Creek Ruin. A collection of six arrows from the Gila Cliff Dwelling are described as having been hafted with pitch (Anderson et al., 1986:185). A knife found in Ceremonial Cave in the Hueco Mountains, East of El Paso, Texas, was described by Cosgrove (1947:62) as having been cemented together with pitch. While he notes that atlatl darts in the region had no resin employed in hafting, many arrow points were hafted with pitch. Another knife collected by Sayles during a 1932 archaeological survey of West Texas is hafted with a resin that strongly resembles lac exudate in catalog photographs (ASM# GP-16230). This knife was transferred to the Texas Archaeological Research Laboratory (TARL) in Austin in 2005 along with other artifacts found in Ceremonial Cave. As with other branches of the Mogollon cultural group, the Jornada Mogollon would have had access to both pine pitch from the higher elevations and insect lac from creosote bush, which is found in the lower elevations around El Paso, as shown in Chapter 2. Further analysis is required to confirm the presence of lac in Jornada Mogollon artifacts, particularly in projectile points, but there is a strong possibility given the documented use of lac by Mogollon branches living farther north.

Hohokam and Salado

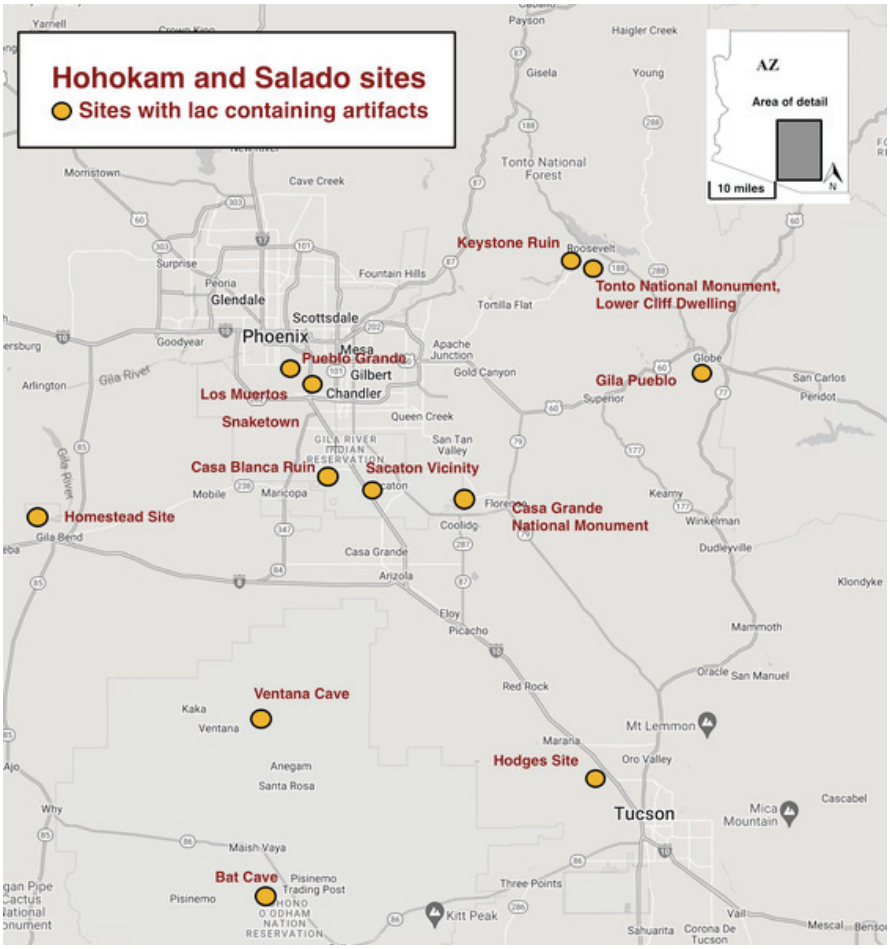

Figure 28 Map of Hohokam and Salado sites with lac containing artifacts.

There are two Salado turquoise mosaics at the ASM from Tonto-Roosevelt province. One is a frog effigy (Figure 26 B), from Keystone Ruin, and the other is cruciform with turquoise on wood, from Tonto Cliff Dwellings, Lower Ruin. The mastic on both fluoresced bright orange, probably indicating insect lac as the mastic. In her ethnobotanical study of Tonto National Monument, Bohrer (1962:83) notes the use of lac and pine resin as adhesives in the area given the proximity to two different ecosystems, or life zones in her terms. Another Salado object from the Los Muertos site, a pottery vessel with lac repairs is in the collections of the PMAE.

There are very few surviving Hohokam turquoise mosaics in part due to the burial practice of cremation and due to poorer preservation conditions in the lower desert region. One Hohokam frog effigy mosaic from the Homestead Site (ASM#1997-184-15) was examined under UV light but there was little fluorescence due to the tightness of the tesserae joins. It was not sampled for other analysis due to possible funerary association. Given the strong adhesion of the turquoise, I suspect the substate is lac. Jernigan (1978: Plate 4) has a photo of two Hohokam mosaics from Casa Grande one of which he notes is made with lac mastic. Haury (1976:298) stated that no intact mosaics were found at Snaketown, but shaped tesserae were, indicating they were being produced there. He also mentions the antiquity of mosaic work among the Hohokam, indicating the technology dates as far back as the Vahki phase in the early Pioneer period, around 300 CE.

Haury reported on a collection of inlaid shell jewelry including rings and bracelets found at the Los Muertos and Los Guanacos sites. He states the turquoise was "cemented with a black substance, probably pitch" (Haury 1945:157). These objects reside in the PMAE collections and in the color catalog photos the mastic resembles lac. A frog effigy mosaic was also found at Los Muertos that became very controversial due to questions over its authenticity. According to Wilcox (2003:92-93) the frog had been faked by Frank Cushing who had originally been hired in 1886 to direct the Hemenway Southwest Archaeological Expedition and excavated the Los Muertos site. He was replaced by Jesse Fewkes in 1889. Haury worked on Cushing's reports years later for his dissertation and suspected the mosaic had been faked or badly restored, the underlying original mastic being overcoated with a shiny black material resembling tar. The suspicions were confirmed by UV light analysis by Stephen LeBlanc of the Peabody Museum in the 1990s.

Another form of ornament made by the Hohokam, apparently exclusively and no later than the Sedentary Period, is etched shell. Pomeroy (1959) examined fifteen of twenty existing examples of Hohokam etched shell accessible at the time from seven different sites. While Pomeroy provides useful illustrations and catalog information for the shells, he provides no more insight about the resist material identification, suggesting a pitch or tarry material (1959:13). Haury (1976: 318-319) also describes the resist material for etched shell as pitch or tar like substance in discussing examples from Snaketown and Hodges Ruin. The etching process includes the application of a resist in a design on the shell that will result in the raised pattern after immersing the shell with resist in an acid bath, possibly made of fermented fruit, by which the exposed shell is eroded. Haury reports that Gladwin had the mastic from a Snaketown example chemically analyzed that confirmed the material was organic but did not confirm its source. Kelly (1978:120) reported that mesquite gum was suggested as the resist material for the Hodges Ruin piece. Mesquite gum would probably immediately dissolve in an acid bath and its use for this purpose is unlikely. Christina Bisulca and I examined the Hodges Ruin example with UV light in 2016 (Figure 29A) and it fluoresced a bright red, probably indicating not only lac, but *Tachardiella larreae* from *Larrea tridentata* given the color (Bisulca et al., 2017).

A large and complete *Laevicardium elatum* shell was donated to ASM (#6550) in 1929 or 1930 that had been found in the Tucson Mountains at the Huntington Site. The shell interior and exterior surfaces are etched with elaborate patterns and are also over painted with patterns in shades of green and red on both sides, with more paint remaining on the interior. None of the resist material remains except for a slight brown staining in the grooves of the etching, possibly indicating it was lac. There was no fluorescence when examined with UV light. Lac was used as

the resist material for etched shell made by the Sacaton Phase Hohokam according to Nelson who surveyed these kinds of objects in ASM and other museum collections (1991:65-67).

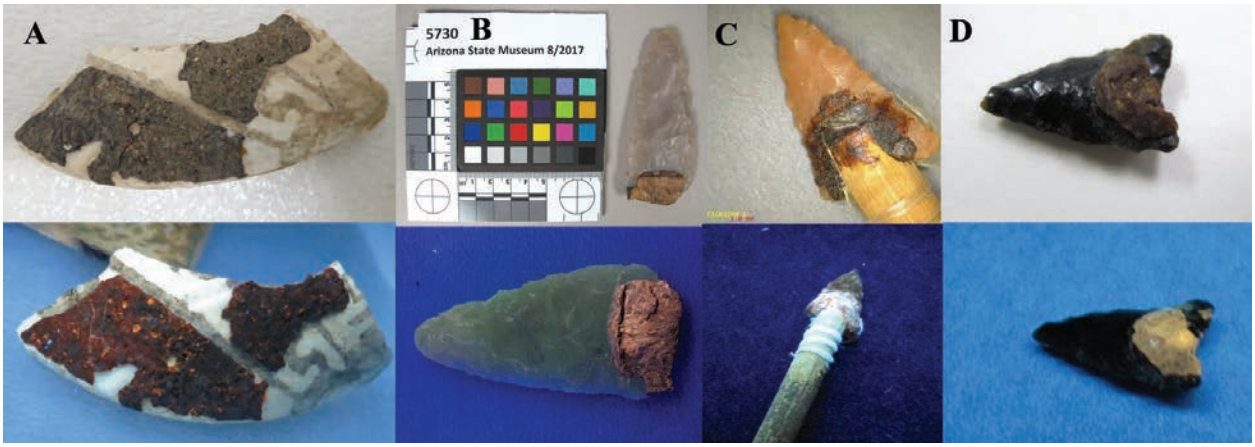

Figure 29 Archaeological objects with insect lac components also shown under UV light, illustrating variations in lac fluorescence. **A** Etched shell with lac resist attached, Hohokam, Hodges Ruin, ASM#A-22445-X-3 **B** Biface with lac hafting material, Ancestral Puebloan, Kayenta Province, Tsegi Canyon, ASM#5730 **C** Arrow with lac hafting material and sinew, Hohokam, Casa Grande, NPS #CAGR3260-A **D** Arrow point with lac hafting material, Hohokam, Tanque Verde Cave, ASM#18487.

The Hohokam also used lac to haft arrows. Two arrow points from Casa Grande fluoresced orange at the joint with the foreshaft confirming the presence of lac. Both arrows date to the Classic Period (see Figure 29C for one example). Another arrowhead separated from its shaft had been secured and concealed with cellophane tape. Once the tape was removed it appeared lac was still present on the point. Under UV light the presence of lac was confirmed. See Figure 29D. Another arrow found in Bat Cave near South Mountain had both lac in the nock and was painted with lac for decoration (Bisulca et al., 2017:Figure 6A).

The largest collection of Hohokam associated lac artifacts at ASM came from Ventana Cave. As with the Ridge Ruin excavation, Ventana Cave lac was found in various stages from raw material to modified components of artifacts. This collection included lac attached to the host plant, *Larrea tridentata,* as a botanical and entomological specimen; sticklac with all but the

stem wood removed; a wooden handle with a ball of lac attached to the top, probably a lac application tool; and a small smooth ball of processed lac that may have been part of an arrow maker's kit. The artifacts with lac from Ventana Cave were utilitarian, unlike the elaborate ornaments found in Ridge Ruin. In addition, there were several arrow fragments with lac as a hafting material and a large sherd of pottery with a hole filled with lac as a repair. The latter was the only example of pottery repair of Hohokam origin in ASM collections. A search of the ASM database from the Save Americas Treasures Pottery Project (2000-2011) of more than 20,700 whole vessels indicates there are 2455 Hohokam pots in the collection of which 1,595 had repairs and of those, only 191 were cultural repairs none of which included indigenous adhesives. Most repairs were mechanical with drill holes for cordage ties (ASM pottery database, White et al., 2009).

The last type of Hohokam objects found with an insect lac component were lac coated balls. There are three such balls from the Salt Gila Province, Sacaton vicinity at ASM. To date no other balls from an archaeological context with lac coating have been found in on-line collections, though uncoated stone balls from the region are common. These balls are illustrated under UV light in Figure 30, and digital x-ray photos reveal the cores of two of them in Figure 31. A third ball brought in to the ASM Conservation Lab for examination was also x-rayed. A sample had been taken earlier for FTIR analysis identifying it as insect lac. The x-ray showed there was no core at all. It must have taken quite a bit of lac to make that ball. It had been contained within two large shells and was perhaps not meant to be a kicking ball like those with cores but was instead intended for use in ornament manufacture. The ball and shells were found in the upper levels of a wash not far from Oatman Flat, south of the Gila River.

Haury (1945:140) describes stone balls found in the vicinity of the Los Muertos site and suggests their most likely use was in kick-ball games, as Russell (1908) informs of the Piman (Akimel O'odham) lac covered kick balls in the twentieth century. Haury (1945:141) recounts that Pimans would repurpose found Hohokam balls, believing them to be powerful, and noted that both wood and stone balls would be coated with creosote gum. See Chapter 4 for further discussion of historic coated balls.

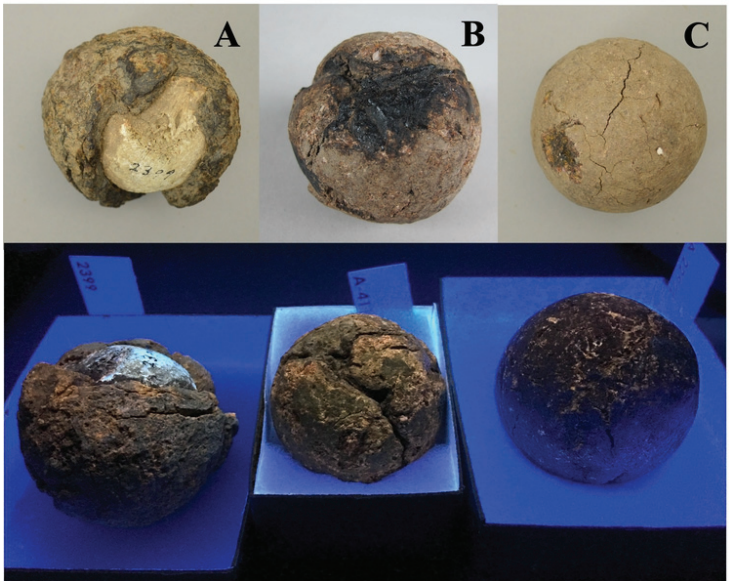

Figure 30 Three Hohokam lac balls in daylight and UV light **A** Hohokam lac ball, Casa Blanca site, bone core (ASM#2399). **B** Hohokam lac ball, Salt Gila Province, wood core (ASM#A-41156). **C** Hohokam lac ball, Salt-Gila Province, stone core (ASM#A-22922).

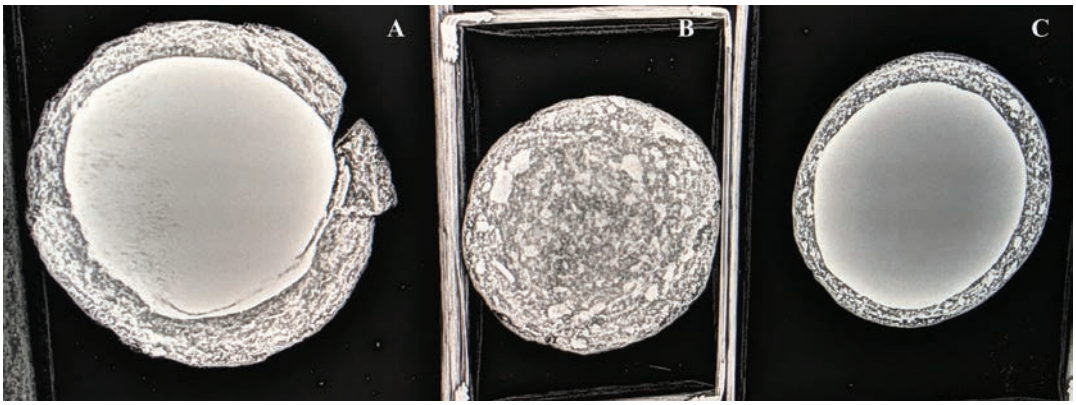

Figure 31 Digital x-radiography of three Hohokam lac Balls. **A** Ball with bone core (ASM# 2399) **B** Solid lac ball with no core, owned by J. Holcombe. **C** Ball with stone core (ASM#A-22922). Photos by Gina Watkinson, ASM.

Patayan

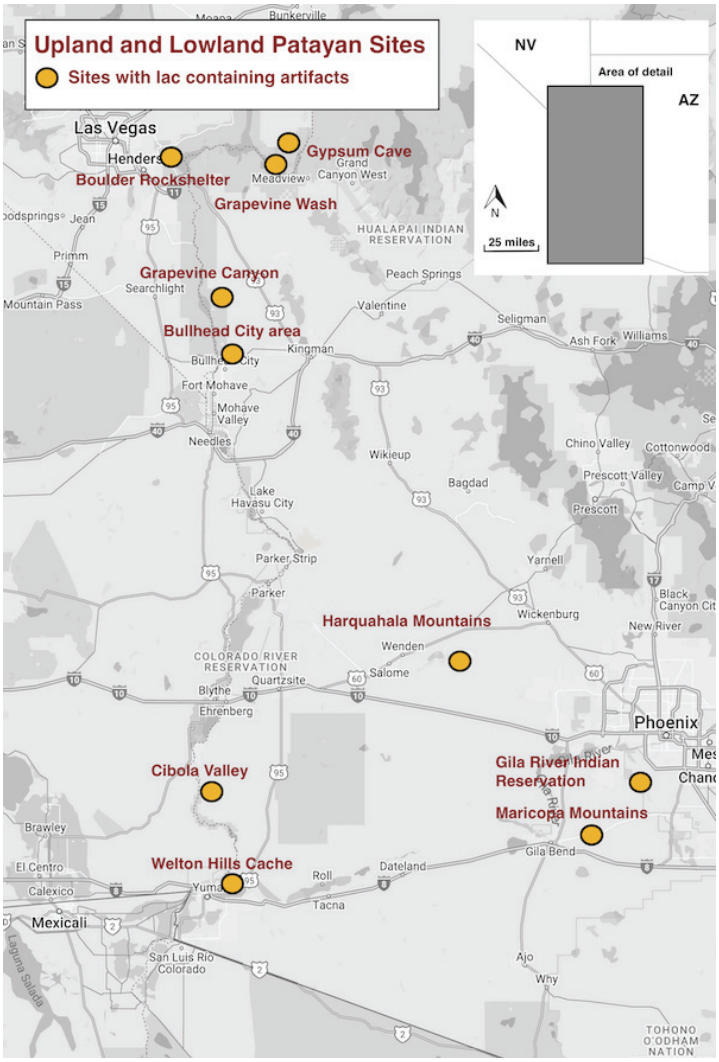

Figure 32 Map of Upland and Lowland Patayan sites with lac containing artifacts

Euler and Jones (1956:88) describe an early example of the hermetic sealing process used in the Southwest where food or other perishable material is stored inside a ceramic vessel sealed with a lid, usually of a rounded base of another jar attached with lac resin, thereby protecting the food from pests, and slowing processes of decay. Euler believed the storage jar found in a cave in the Kingman area he used as an example (MNA #1019/L) was a Lower Colorado Buffware type, which could date to 1105-1505 CE based on radiocarbon dating of the plant fiber. The jar

was filled with processed mescal (agave). Intrigued by the hermetic sealed jar, Euler conducted a study of the practice. His findings on the historic practice of hermetic sealing with lac will be discussed further in Chapter 4. He examined another privately owned ceramic lid that had lac around the rim for sealing to a vessel below. The lid was found on the west side of the Ajo Mountains and was a Sells Plainware type ranging from 1000 to 1500 CE, indicating another Hohokam piece found with lac (Euler and Jones 1956:91).

Bayman et al. (1996) report on a cache of Patayan Lower Colorado Buffware jars found in a cave near the Trio Mountains in La Paz County, Arizona. Three of the five jars had organic resin sealant on their rims. Three of the jars also had crack repairs with the same resin. The jars are illustrated in reassembled form showing the repairs and lid sealing (Bayman et al., 1996:134).

Their analysis of the sealant resin with ethanol and potassium hydroxide, indicates the material is indeed insect lac and not pine resin.

Among the collections attributed to the Lowland Patayan at ASM, eight are pottery vessels, seven with lac used for hermetic sealing, some with lids intact, and one other that has lac for crack repairs (Figure 33). Five Upland Patayan artifacts examined with UV light from the Lake Mead collections of the National Park Service at WACC in Tucson also have lac components. Three are stone blades and two are wood artifacts. One knife (LAME 10716) from a Nevada Rockshelter site had a large wad of red colored lac attached at the base of the blade forming the handle. A biface with lac hafting material still attached to the base of the blade (LAME 11622) came from Grapevine Wash and dates from 901-1150 CE (Figure 34). Two additional artifacts at the Phoebe Hearst Museum are bone awls with resin handles from caves in

Grapevine Canyon in Clark County, Nevada (PHM 2-11652 and 2-11653). The handles could be lac but require additional analysis to be certain.

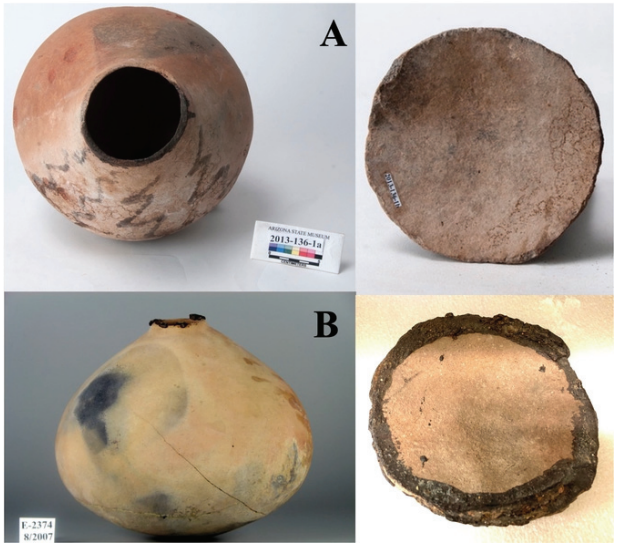

Figure 33 A Pottery jar and lid: Lowland Patayan, Parker Buffware, Mohave County, AZ. Pot rim and lid have lac as evidence of hermetic sealing for perishables storage (ASM#2013-136-1). **B** Pottery jar and lid: Lowland Patayan, Lower Colorado Province, Colorado Beigeware, Maricopa County, AZ. Pot rim and lid have lac as evidence of hermetic sealing for perishables storage (ASM#E-2374).

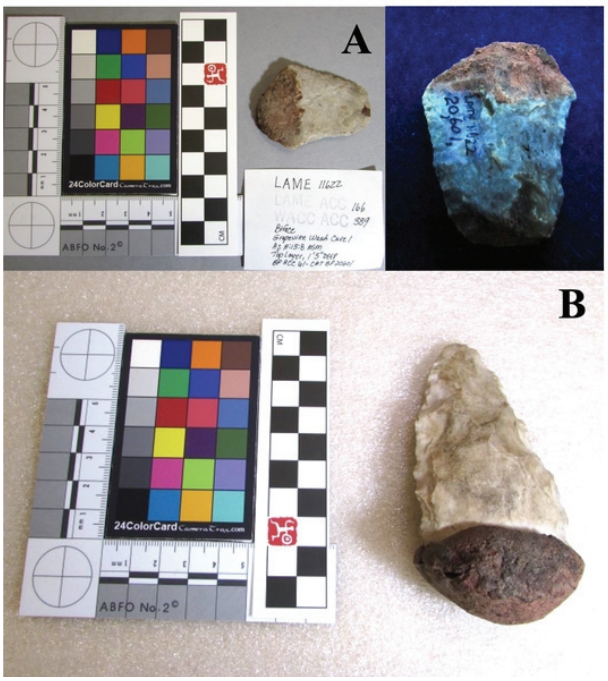

Figure 34 A Biface in daylight and UV light showing lac fluorescence. Upland Patayan, 901-1150 CE, Grapevine Wash, Cave 1, Lake Mead, NPS#LAME11622) **B** Knife, Upland Patayan, chert stone blade with solid lac handle, Rockshelter 1, Lake Mead, NPS#LAME10716

Northwestern Mexico

Edward Davis, a San Diego area rancher, and collector for the Heye Museum in New York (of which the collections formed the foundation of the National Museum of the American Indian, Smithsonian in 1989), usually acquired historic objects but when opportunity arose, collected archaeological pieces also. While with the Seri he collected a set of large archaeological ceramic jars with small mouths and lac sealed lids from a cave on Pico de Johnson, inland from Isla Tiburon. Felger and Moser (1985:92) published a photograph of the pots in situ and noted that they contained cardón (*Pachycereus pringlei*) cactus seeds. At least one of these jars is in the NMAI collections (#16/4324). Davis collected other historic era jars and artifacts with lac from the Seri and other indigenous people around the Southwest that will be described in Chapter 4.

According to Bowen's (1976) archaeological survey of the Sonoran central coast, the prehistoric artifacts collected by the Mosers, linguists who lived at Desemboque for many years, would be donated to a museum in Hermosillo. That museum is now called the Museo Regional de la Universidad de Sonora, and by good fortune, published its catalog of archaeological objects last year, making them visually accessible (Hinojo et al., 2021). The catalog refers to the large style of prehistoric Seri storage jar or olla as the Tiburón Lisa type, also referred to as Tiburón Plain or Eggshell pottery for its notable thin walls. A photo of a Tiburón Lisa olla donated by the Mosers is pictured in their Figures 24 and 62 (Hinojo et al., 2021:37, 59). It is difficult to be certain from the photos, but there may be lac residue on the rims, requiring future investigation.

The ASM collections have six archaeological artifacts from Northern Mexico that have lac components. One is large pottery jar (ASM# A-36794) with lac used for crack repairs that

was originally cataloged as the prehistoric Trincheras Purple-on-Red type but is now thought to be a protohistoric style related to the Hohokam called the Oquitoa type according to catalog records. Another object is an arrow foreshaft fragment with lac decorative paint from a Northern Sierra site east of Babícora and south of Paquimé in Chihuahua, Mexico. There are also four complete bottle gourds (*Lagenaria siceraria)* with lac around the rims as sealant for plugs to contain the amaranth seeds that were contained inside (Figure 41).

Prehistoric exchange of objects containing lac

The presence of shell-based prestige or status objects also containing lac, such as etched shell, trumpet shell, as well as lac coated balls for ballcourts, described above, were typically found in burial or ballcourt contexts from the Hohokam Colonial and Sedentary periods. In the Classic period with the shift from ballcourt to platform mounds the ornate etched shells and trumpets decline while mosaic and inlaid shell increase, also an object type found made with lac mastic. These objects were also found in ceremonial and burial contexts inside and outside the Hohokam region. McGuire notes that direct access to shell sources may have also declined during this era and that shell manufacture increases in both the Phoenix and Tucson Basins, diminishing in the Papagueria. These trends indicate that the previous exchange system was changing and probably breaking down. (McGuire 1987, 1991).

In Doyel's discussion of Hohokam shell exchange he emphasizes the material culture found at different sites through time. He notes that the evidence shows that the Hohokam were willing to travel some distance to acquire raw materials for production of goods and that long distance trade was most intense in the Colonial and into the Sedentary periods, especially up to the Verde Valley and Agua Fria area. The Hohokam were acquiring their raw materials from the

source. During this period the Papagueria and Phoenix Basin had an asymmetrical exchange relationship, and he notes that in the Classic era Gila Bend stopped supplying shell, which concurs with McGuire's discussion of the same. With the reorganization Casa Grande and Las Colinas became more predominant shell manufacture centers. Doyel describes the different theories that archaeologists had about Hohokam procurement at the time, whether direct access, use of middlemen, outside incursions or integration. He points out that the Hohokam were geographically situated to facilitate the movement of shell and salt, plus desert climate adapted products to others for whom such products would be rare. He includes among these products: cotton, agave, and lac (Doyel 1991:244). Doyel also suggests there may have been different spheres of trade with some being for luxury goods between elites and other spheres for utilitarian goods and another for social goods such as textiles, pottery and baskets, craft specialties. With these spheres, the core and peripheries function more as interacting adaptive zones than, as he phrases it, spokes around a wheel (Doyel 1991).

Vokes and Gregory discuss in detail the prehistoric trade routes that may have been used to transport shell from both the Pacific and the Gulf Coast, some of which made its way to Zuni. They identify five possible routes from the Gulf, four at mouths of rivers and one extending across Papagueria. The authors also describe the broader exchange systems between Mimbres, Chaco and Wupatki and the Hohokam trade system in the South and other trade routes among and between them, as well as their variability and transformations through time regarding the primary raw materials found in exotic or prestige trade items, which include the trumpet shell, macaw, copper bells and turquoise (Vokes & Gregory 2007). With the disruption and decline of the four exchange systems mentioned above after approximately 1250 AD and the rise of the Paquimé system it is unknown whether lac continued to be an item traded through the new

routes. Lac does appear in Mogollon artifacts which date well into the 1300's in the ASM collections.

Summary and Conclusions

The examination and analysis of artifacts containing lac from an arid Southwestern archaeological context, both in person and online, culminated in 124 manufactured objects and 2 archaeobotanical specimens, collected from 49 archaeological sites. The numbers of objects and sites by cultural group are provided in Figure 35. Of the 124 artifacts, 63 of them contain lac with certainty, 13 probably contain lac and 30 possibly contain lac, the latter two groups requiring further examination and analysis to gain certitude.

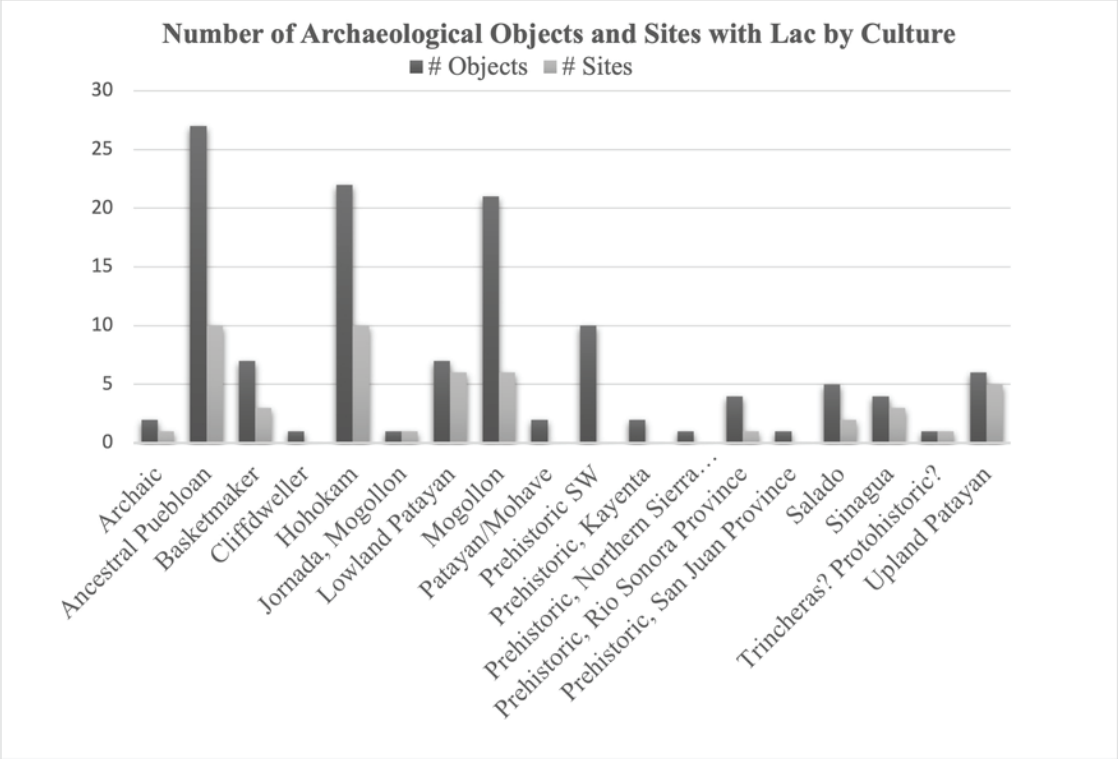

Figure 35 Chart of the number of archaeological objects and sites by culture

The distribution of the lac containing archaeological artifacts ranges across at least five Western States and two States in Northern Mexico. The range in time of the lac containing artifact production is also extensive. With further analysis to provide certainty, it is possible the

use of lac to haft weapons extends back to the Late Archaic in Utah with Cowboy Cave. Other projectiles confirmed to have been hafted with lac date to the Basketmaker III era in Northern Arizona. Mosaic work with lac mastic has been shown to date to the early Pueblo eras at Chaco Canyon. Examples of lidded jars hermetically sealed with lac, found stored in caves, could date back as far as the 700s CE.

The most common types of archaeological objects made with lac are listed by culture in Table 11. It is notable that a few object types, and consequently, lac uses faded out over time in transitions between different prehistoric phases and the greater transition period between prehistoric and historic, or post contact. Hohokam etched shell phased out between the pre-classic and classic periods. Mosaic fabrication in the form of jewelry continued into the historic period.

Table 11: Types of Archaeological objects with lac by cultures

Object name	Cultures
Arrow, arrow parts	Hohokam, Mogollon, Papagueria
Awl	Prehistoric Southwest, Patayan
Ball	Hohokam
Biface/Blade	Ancestral Puebloan, Virgin Branch Puebloan
Dart	Archaic, Basketmaker
Dice/Gaming piece	Basketmaker, Ancestral Puebloan
Bottle gourd	Prehistoric, Rio Sonora Province
Drill	Basketmaker, Prehistoric Southwest
Handle, wood	Ancestral Puebloan, Kayenta Province
Knife	Ancestral Puebloan, Jornada Mogollon, Mogollon, Upland Patayan
Ornament, etched shell	Hohokam
Ornament, mosaic	Ancestral Puebloan, Hohokam, Mogollon, Salado, Sinagua
Pottery	Lowland Patayan, Hohokam, Salado, Prehistoric Seri, Trincheras
Scraper	Ancestral Puebloan
Wooden artifact	Hohokam, Upland Patayan
Raw material	Hohokam, Ancestral Puebloan

era in Puebloan communities but not in the communities of the lower deserts. Hafting of arrows with lac continued in desert communities into the historic era. Hafting of knives in the historic era, more often with metal blades, have not been found to be hafted with lac. Finally, dice or gaming pieces have not been found with lac as they were in the prehistoric era. As will be shown in Chapter 4, other types of objects made with lac did persist with time and new object types were established.

Finally, it is important to recognize that in the study of any organic resins or other materials used for adhesives in an archaeological context there is a taphonomic bias towards those materials best suited to survive (Kozowyk et al. ,2020). The physical and chemical impacts to organic materials from environmental conditions in burial and other archaeological contexts can cause many of those materials to decay completely. Lac exudate is one of those materials that tends to survive since it chemically crosslinks over time becoming more resistant to deterioration processes, unlike pine resin, which oxidizes and deteriorates more rapidly over time (Bisulca et al., 2017). In other words, lac may be found in archaeological collections when others are not because it is more persistent. Other materials, such as pine resin, animal adhesives and plant gums and starches may have also been used but are less durable and therefore, less detectable. However, in the context of protected caves of the arid Southwest where many perishable materials survived degradation, some of those other materials survive also, reducing the taphonomic bias in those instances. In the mountains regions of the arid Southwest there are more often caves than in the expanses of lowland open deserts. Even lac will deteriorate if exposed to the desert environment if exposed on the surface over centuries. Therefore, the full of extent of the prehistoric use of lac and the use of lac relative to other adhesive materials cannot be fully known.

CHAPTER 4

Ethnographic cultural use of lac scale (*Tachardiella* spp.) documented in anthropological literature and in artifacts found in selected museum and repository collections

Introduction

The advent of the historic era in the arid Southwest related to the intrusion of European colonists in the fifteenth and sixteenth centuries onward, had a devastating and transformative impact on the indigenous people, their landscapes and their material cultures was devastating and transformative. Despite the upheaval and change, daily life endured and people in the region continued to use adhesives to repair broken objects like pottery and to make weapons and tools. They continued to use insect lac exudate as one of those adhesives, particularly in the lower Colorado River basin region, at least through the middle of the twentieth century. Some applications of lac disappeared with the upheaval, including the production of prestige and ornamental objects made in the prehistoric era. Other uses for lac persisted, illustrating some continuity, and some new uses developed in some areas, as will be discussed further in this study.

Evidence of lac use in material culture appears to fade in eastern Arizona and in New Mexico in the historic era. For example, most adhesives documented in Apache material culture and in the Pueblo communities of New Mexico have been pine resins based on examination and analysis as well as with online examined collections (Bisulca et al., 2017). There was one outlier specimen, indicated by a label “cement for watertight baskets” collected from the Apache by Edward Palmer in 1868. Apache baskets are known to be waterproofed with pine resin, not lac. However, the material in question (NMNH#E7528-0) was identified by a botanist at the National Museum of Natural History, Smithsonian (NMNH) in 1915 as “a lac deposited by an insect on

the leaves of *Covillea tridentata*." The catalog image of the material does look like lac and not pine resin. Given how much material Palmer collected, it is not too much a surprise if there was a mix up. It is probably lac, but was probably also not used on baskets, and may not have been collected from the Apache.

The documentation of archaeological objects made with lac found in museum collections was limited and often inaccurate, as described in detail in chapter 3. Inaccurate and limited museum documentation of ethnographic museum objects made of lac in the historic era persisted. Absence of detailed and accurate provenance of museum objects obscures the ethics of their acquisition (Kreps 2012). Research of the collections for this study has attempted to correct and supplement the documentation of objects made with lac, to reveal more information about their provenance when possible. Contemporary ethnographic research was not used as part of this study since objects manufactured with lac are no longer produced in significant quantity in the Southwest. Ethnographies produced during the time that lac was in cultural use were utilized. None of these ethnographies have been found to be rejected by the people about whom they are written based on searches in the literature, however, I would welcome any knowledge of such information.

This chapter, using the same methodologies described in Chapter 3, presents the results of historic era anthropological collections research and ethnographic literature review.
In person examination and analysis of ethnographic collections were concurrent with archaeological collection research at the Arizona State Museum (ASM) with the same permission process for sampling. In addition, I examined ethnographic collections at the Amerind Museum in Dragoon, AZ using UV light and catalog records. Many of the museums, monuments, and cultural centers I visited had ethnographic as well as archaeological objects on

exhibit or in storage, which I was able to examine. I used similar tabular forms for researching and documenting the ethnographic collections of museums and other institutions online as noted in the previous chapter.

More than twenty cultural groups who used lac for manufacture of material culture are arranged by geographical region (Figure 36) and then discussed individually within cultural groups living in those regions, along with supporting information found in the literature. All of these cultural groups in the United States originally occupied larger areas of land than the current reservations established by the U.S. federal government. Lands currently occupied by the indigenous groups in Mexico were also larger in the past These regions include the Upper Colorado River and Mojave Desert, describing lac use by peoples living in southern Nevada, central eastern California, northwestern Arizona, and southwestern Utah. A second geographic region is the Lower Colorado River, describing lac use by peoples from southwestern Arizona and southeastern California. The third geographic region in this study is the Sonoran Desert and lower inland river valleys, with lac use by peoples living in south central Arizona. The fourth geographic focal region is the State of Chihuahua, Mexico, where lac is used by the peoples of the Sierra Madre Occidental. The final geographic region described in this study, the State of Sonora Mexico, includes discussion of lac use by some of the peoples living in western Sonora, along with additional consideration of the traditional ecological knowledge incorporated into the use of insect lac. The only cultural group not discussed in this region is the Seri (Comcáac) because their use of lac is covered later in much greater detail in Chapter 5.

The current chapter will also discuss many of the early collectors of historic era material culture in the region. Several of these explorer naturalists later became ethnobiologists and/or anthropologists and were aware of insect lac in the arid Southwest early on. Their efforts

provided the groundwork and evidence for future lac research in the region. These collectors not only acquired artifacts but also entomological and botanical specimens of *Tachardiella* spp. and their host plants concurrently, increasing the certainty of the identification of the material once it was applied as a component of artifacts.

Figure 36 Map of cultural groups using lac in the historic era

Review of literature and artifact collections for cultural use of lac in the historic era

A variety of names have been used in both the anthropological literature and in catalog records of institutions housing collections with artifacts containing lac for the different indigenous groups who used lac over time. Indigenous languages were oral at the time of European contact and variations of orthographies for indigenous group names resulted. In this

chapter the orthography of the authors' text where indigenous group names were found will be used. Table 12 lists tribal names by current English use, the people's own names for themselves, and names used in the past, including some in Spanish, since many of the names listed will be referenced in discussions below.

Table 12: Tribal names of cultural groups who used lac in the historic era.

Tribal Names, Contemporary English	People's Own Names	Historic Names
Akimel O'odham	*Akimel O'odham*	Pima, River People
Cahuilla	*Ivilyuqaletem*	Coahuilla
Chemehuevi	*Nüwü*	Chemehuevi
Cocopah	*Kwapa*	Cucupa, Cocopa
Havasupai	*Havsuw' Baaja*	Havasupai
Hualapai	*Hualapai*	Walapai
Kumeyaay	*Tipai-Ipai*	Diegueño, Kamia
Luiseño	*Payómkawichum*	Luiseño
Mayo	*Yoremem*	Mayo
Mojave	*Aha Makhave, Mojave*	Mohave
Panamint	*Nümü Tümpisattsi, Timbisha Shoshone*	Panamint
Paiute, Northern	*Numu*	Paiute, Northern
Paiute, Southern Kaibab	*Nuwuvi, Nuwu, Kai'vi'vits*	Paiute, Southern
Paiute, Southern Moapa	*Nuwuvi, Nuwu*	Paiute, Southern
Paiute, Southern Shivwits	*Nuwuvi, Nuwu, Shivwits*	Paiute, Southern
Pima Bajo	*Ob, Ures, Névome*	Pima Bajo
Piipaash	*Piipaash*	Maricopa
Quechan	*Kwatsáan*	Yuma

Seri	*Comcáac*	Seri
Tarahumara	*Rarámuri*	Tarahumara
Tohono O'odham	*Tohono O'odham*	Papago, Desert people
Yaqui	*Yoeme*	Yaqui

Upper Colorado River and Mojave Desert

Chemehuevi

The Chemehuevi people live along the Colorado River bordering Lake Havasu in San Bernadino County in southeastern California on a reservation, established in 1970. The Chemehuevi also live farther south along the Colorado River on the Colorado River Indian Tribes (CRIT) Reservation, established in 1865, with lands between Arizona and California. CRIT is a federally recognized tribe who originated from four distinct tribes: The Mojave, Chemehuevi, Hopi and Navajo. In the past, the Chemehuevi lived farther north in proximity to the Colorado River in southern Nevada, just south of the Mojave people (Kelly 1934). They were originally the southernmost branch of the Southern Paiute people who lived a migratory existence in the Mojave Desert before settling to farm in the Chemehuevi Valley before the construction of Parker Dam (Stewart 1968). Kelly (1934) remarks that the Chemehuevi and Southern Paiute were then nearly indistinguishable culturally. Because the Chemehuevi were still living in the upper Colorado River area when examined artifacts with lac were collected, dating 1903 to 1922, discussion of their association with lac is included here rather than with the lower Colorado River tribes.

Among the notable lac containing objects collected from the Chemehuevi people was processed lac used for painting arrows. Alfred Kroeber, founder of the Anthropology Department

at University of California, Berkeley, collected three samples in 1907. Isabel Kelly, a former student of Kroeber's, collected another example of arrow paint made of lac during her fieldwork among the Southern Paiute and Chemehuevi from 1932-1934. Half of this object, illustrated in Figure 37, is coated in bright red orange paint resembling vermillion. Kelly's field notes state that the red paint came from the Moapa (Paiute) and the color was applied by dipping *Apocynum* twine into the mixture of the two, and then wrapping it around the arrowshaft to apply the paint (Fowler and Garey-Sage 2016:97). The lac may have served as a binder more than a colorant in this case.

In addition to paint, Kelly and others collected Chemehuevi arrows with lac as the hafting adhesive. The arrows shafts were often made of arrowweed (*Pluchea sericea*) stem wood based on catalog records. Smith (2006:143) suggests the Chemehuevi joined the arrow points using glue from the arrowweed itself, which would most likely be *Tachardiella pustulata* instead of a plant gum or resin. Another object donated by Kelly was an awl made of a badger penis attached to a bone handle with lac, which she calls *tisanimp* in the Chemehuevi language (Fowler and Garey-Sage 2016:101). The final type of object found to include lac are rattles made of gourds attached to wood handles with lac adhesive. A rattle collected by Kelly is shown in Figure 37, where the lac is clearly visible at the join. Edward Davis, a rancher from San Diego who was hired to collect around the West for the Museum of the American Indian in New York City, collected rattles from the Chemehuevi as well as several other tribes. Like Kelly, he identified the material used to join the gourd and handle as creosote gum. Both Kelly and Davis collected samples of processed lac glue. Kelly's "creosote bush gum, used for attaching foreshafts and arrowpoints" is a flattened cone shaped mass of lac at the PMAE, catalog #34-24-10/3708. Davis's example, collected in 1922 in the Chemehuevi Valley in San Bernadino County, CA is

called “gum/pitch/resin” on the online record, but the scanned typed catalog card describes it as a “ball of gum from the creosote plant, used for glue”. It is a nearly round ball of dark brown lac, reminiscent of the Hohokam balls described in Chapter 3, and is in the collections of the National Museum of the American Indian (NMAI,) catalog #11/6875.

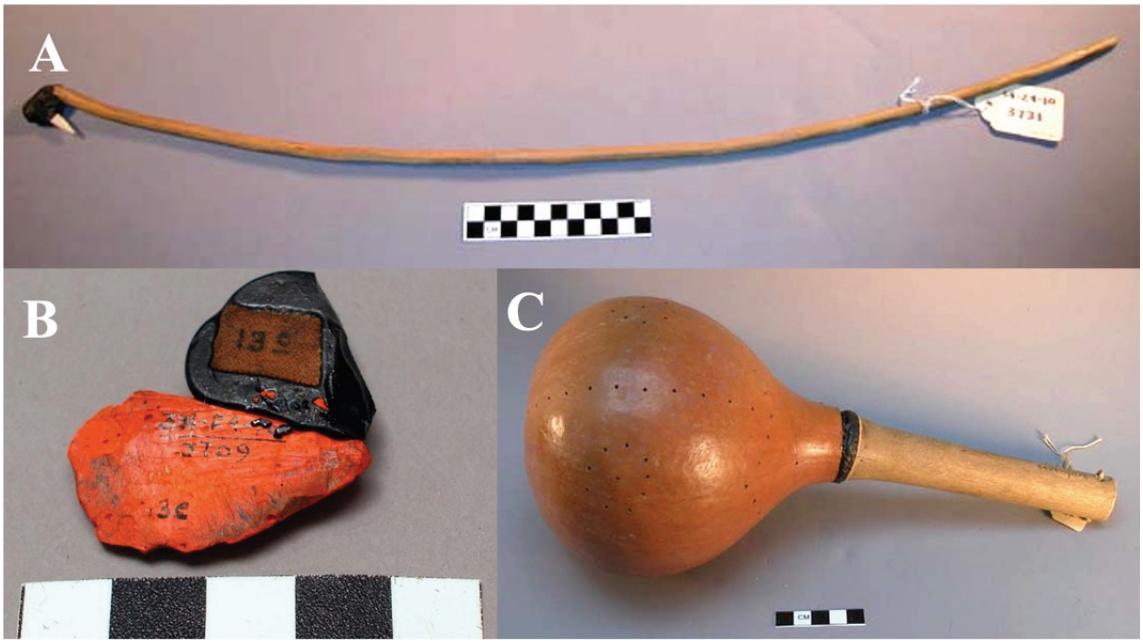

Figure 37 Three lac containing artifacts collected by Isabel Kelly from the Southern Paiute-Chemehuevi near Parker, Arizona during field work in 1933. Kelly identified the resin in all three as creosote bush gum **A** Chuckwalla lizard hook; lac adhering bone tip, PMAE#34-24-10/3731 **B** Mixture of red paint and lac, used to decorate arrow shaft PMAE#34-24-10/3709. **C** Rattle, gourd with handle attached with lac. Made by Henry Hanks, PMAE #34-24-10/3722. Images are from open access online catalog records, courtesy of the PMAE.

Carobeth Laird, an ethnologist who lived among the Chemehuevi and published an ethnography, mentions lac several times in her study. For example, the Chemehuevi made baskets and pottery for storage containers and Laird (1976:6) noted that they stored seeds in baskets with shaped pottery lids sealed on with greasewood gum, which was lac, specifically *T. larreae,* since greasewood was another common name for creosote bush. Laird notes this herself (1976:107) in providing the Chemehuevi name for the plant, *yatampi.* The use of lac even

features in two stories that Laird recounts (1976:168, 189) “How Coyote Went to War Against Gila Monster” describes seed storage with lac sealant, and “How Bat Killed Rattlesnake” describes a girl who mends a knife with lac after bringing her sister back to life. While I searched all the online museum collection sources for evidence of lac sealant on Chemehuevi baskets and pottery, I was not able to locate any.

Havasupai

The Havasupai people live in Havasu Canyon in northern Arizona, and since 1975 also have restored lands on the rim of the Grand Canyon, all of which are surrounded by the Grand Canyon National Park. The Havasupai are well known for their basketry. In the past they coated various sized twined baskets with pine pitch for water storage. They also made basketry for cooking since pottery was less often produced, and they often traded for pots with the Hopi (Whiting 1985).

Leslie Spier, an anthropologist, conducted field work with the Havasupai while working as a graduate student for the AMNH in 1918 and 1919. The objects he collected are at the AMNH and his field work was later published as a major ethnology (1928) of the Havasupai. Among the more than two hundred Havasupai objects he collected was a plain brownware pottery olla, AMNH# 50.2/1668. A deep crack extends across more than half of the pot above the shoulder, and it is smeared all the way with a brown colored resin. Spier remarked in both his field notes from that period, housed at MNA archives, and in his book that pottery cracks were sometimes repaired with an alkaline clay after firing, but the repair on the pot in the catalog photo does not resemble clay, but instead a resin, probably pine pitch or lac. Further analysis is required to be certain. Spier also collected several bows and arrows, now in AMNH collections.

It is difficult to ascertain if there is adhesive present from the photos, but Spier says glue was applied between the point and foreshaft below sinew wrapping, and between the foreshaft and lower shaft on compound arrows. Unfortunately, Spier did not specify what the glue was made of in either his notebooks or his book.

Another anthropologist, Alfred Whiting, spent a year working on ethnobotanical research with the Havasupai in 1941. He had been the Curator of Botany for the MNA in the 1930s and his field notes from the time are in the archives there. His notes relating to that project, including notes from informants were published posthumously in 1985. In describing Havasupai hunting tools and techniques, Whiting noted that arrowheads were set in the shafts with lac that they acquired through trade with the Mojave. The editors included a footnote based on personal communication with Robert Euler in 1983 that the lac may have also been found along the Big Sandy River, an intermittent and perennial stream that begins in the Hualapai Indian Reservation. Euler said it hadn't been seen growing on *Larrea* (Whiting 1985:37). Perhaps the source of lac was instead *Pluchea* and the lac was *T. pustulata.* In the chapter on plants used by the Havasupai, Whiting includes both creosote bush and arrowweed. For *Larrea* he states the following based on an informant, B.B. (Whiting 1985:228):

> This bush, which grows only in the lower deserts, was the habitat of a lac producing insect. The lac was formerly an important element in native trade. Although the Havasupai themselves no longer collected it in 1941, they obtained it in trade from the Mohave and, in turn, traded it to the Hopi. A chunk of lac, two or three inches in diameter, could be traded for a blanket. The Havasupai used lac to attach arrowpoints.

Whiting's description of arrowweed, for which he used an older name *Tessaria sericea,* does not mention the presence of lac, but he does note that the plant grew abundantly in the village (Supai) and that it was used for making arrows as well as other objects (Whiting 1985:249).

Hualapai

The Hualapai people live in an area west of the Havasupai, extending along the south rim of the Grand Canyon, following the Colorado River. The only Hualapai artifacts found with lac were online in NMAI collections. They are three rattles collected by Edward Davis in 1920 in Kingman and Hackberry, Arizona. It is notable that this area is where Colton found the heaviest concentrations of *T. larreae* in his survey, described earlier. The rattles have thick and visible deposits of lac at the join between the gourds and the wood handles. Euler describes a similar object he called a Shaman's rattle, he found during fieldwork at a rock shelter site, NA4378, in Mohawk Canyon just south of the Colorado River on the Hualapai Reservation. He says the gourd is sealed to the handle with lac (Euler 1958:166). Kroeber (1935:121) has an illustration of three rattles, with what appears to be lac adhesive, stating that the rattles were used in medicinal practices as well as for dancers, also mentioning the Hualapai name for the gum of creosote bush, *tepi'l* (1935:32).

Euler and Jones (1956:90) describe a Hualapai woman's recollection of keeping food stored in sealed jars in caves using "heated sap from the greasewood plant" which would have been *T. larreae* from the creosote bush, again commonly called greasewood at the time. Euler and Jones (1956) provide several examples of hermetic sealing with lac on pottery jars from a variety of Southwestern cultures over time, including Patayan (c. 900-1500 CE) and in the historic era, the Hualapai in the upper Colorado River area (Euler and Jones, 1956:90).

Panamint

The people formerly known as the Panamint are now federally recognized as the Timbisha Shoshone, who live in the Death Valley Indian Community in Inyo County, California, near the Nevada border. In 1891 Frederick V. Coville, the botanist who published accounts of

both *Larrea tridentata* and *Pluchea sericea*, participated in the Death Valley Expedition. This trip was funded by an act of Congress in 1890, to report on the plants and animals of the region. As part of this expedition, Coville came upon a village of Panamint people living in the Panamint Mountain area in Inyo County, California and documented their wild food procurement, material culture and, lifestyle at the time (Coville 1892). Coville mentioned that the Panamint made glues of boiled animal horn, pine pitch and a gum from *Larrea mexicana*. Below is his description of the use of lac by the Panamint (Coville 1892:361):

> Larrea gum occurs in the form of small, reddish, amber-colored masses on the twigs of the shrub, and is deposited there by a minute scale insect, *Carteria larreae*. The crude gum is mixed with pulverized rock and pounded. The product, heated before applying, was once used to fasten stone arrow heads in their shafts, and is at the present time employed for other similar purposes. At Ash Meadows, Nevada, I was shown a broken sugar bowl cover that that had been neatly and firmly mended with this cement by an Indian.

Coville's description was discussed by Sutton (1990:264) who suggested that the addition of sand from the pounded rock could act to delay the cooling of the material, increasing its malleability and utility. He ran tests on heated lac with sand and without, and found that sand alone didn't improve workability, and stated there may have been other additives.

Coville collected a sample of *T. larreae* with some stems present while on the expedition and donated it to the Anthropological collections of the NMNH, #E165099-0. The handwritten note on the envelope accompanying the lac, states "Gum used as arrow glue from the *Larrea mexicana*, Panamint Indians, Cal. F.V. Coville" and the registrar's note includes that it was made by the insect Carteria. Another Panamint artifact made in the late 1800s to early 1900s is a basketmaking awl consisting of a cactus spine with a handle made of lac scale resin, according to the catalog cared of Object #491.P.3136 at the Autry Museum in Los Angeles. Coville remarked

on awls like this, noting they were made with the spine of the devil's pincushion (*Echinocactus polycephalus*) stating they were set in hard pitch for a handle (Coville 1892:359).

Steward (1933:262), who wrote an ethnography of the Owens Valley Paiute, remarked that arrows were "glued with a kind of shellac from sage infected by insects." The Owens Valley Paiute live in an area north and west of the Panamint, north of Death Valley. The sage he mentions was probably *Adenostoma fasciculatum* also called chamise or greasewood, a shrub in the Rosaceae family, common to the California chapparal. This shrub is also a known host of another species of lac scale insect, *Tachardiella ferrisi*, which is not found outside of California and Baja California (García Morales et al., 2016). It is clear from the lac collected by Coville, however, that the Panamint were using *Tachardiella larreae.*

Southern Paiute – the Moapa, Shivwits, Kaibab bands

The Moapa Paiute live along the lower Virgin River in southern Nevada. The Shivwits Paiute live along the upper Virgin River area in southwestern Utah, and the Kaibab Paiute live east of the Shivwits in northern Arizona. Among the many bands of Southern Paiute people, the Moapa, Shivwits and Kaibab were among the first to be visited by ethnographers in the region with the Green and Colorado River expeditions led by Major John Wesley Powell (Fowler and Fowler 1981). Powell's collections from ethnographic work between 1870 and 1873 are in the Smithsonian, NMNH. Powell, who was appointed director of what became the Bureau of American Ethnology not long after, collected artifacts and ethnobotanical materials and information about them from the Paiute.

Seven of the objects and specimens Powell collected from Southern Paiutes in southern Utah were lac or contained lac. Figure 38 shows some of the lac material Powell collected, including raw sticklac from creosote bush, and a collection of processed and molded lac removed

from the stem. Figure 38C shows an image of five knives hafted with lac, which are part of a collection of twenty knives all cataloged with one number. Fowler and Matley (1979:68) illustrate all of them together (Figure 56:156) and suggest they may be Kaibab Paiute in origin. They note that the photograph of a man shown in their Figure 57 may be working on one of those knives. They also suggest the resin on the knives is insect lac based on reference to Colville (1892) and Hoffman (1896). Not shown are two other examples of processed lac, a small loose ball of lac and a ball of lac attached to a stick, described as "gum resin for cementing arrows" in the catalog record, NMNH#E14338-0. Powell also found two globular shaped pottery jars with lac sealant on the rims, one shown in Figure 38D with a lid attached. Fowler and Matley believe the jar is an archaeological vessel, Pueblo II – III, of the North Creek Grayware type that was repurposed by the Moapa Paiute, who added paint and lac adhesive, probably to use for sealed food storage (Fowler and Matley 1979:84).

Figure 38 Specimens and artifacts collected by J.W. Powell from Southern Paiutes, c. 1870-1873. **A** Sticklac specimens, *Tachardiella larreae* on *Larrea tridentata,* NMNH#E14782-0 **B** 3 flat slabs of processed lac, NMNH# E14343-0 **C** 5 of 20 knives hafted with lac, NMNH # E14329-0 **D** Pottery jar repurposed for food storage with lid sealed with lac. NMNH#E14785-0. Images courtesy of Anthropological Collections Management, NMNH, Smithsonian Institution.

Others also collected lac containing specimens and artifacts from the Southern Paiute. A knife (NMAI#2/9532) hafted with lac was collected by artist, topographer, and author Frederick S. Dellenbaugh in 1875 during a trip to retrace Powell's 1871-1872 route of the Colorado River. The knife is nearly identical to those collected by Powell illustrated and described above with the same type of adhesive joining the blade to handle. A bone basketry awl in the Yale Peabody (YPM ANT005364) is also hafted with what appears to be lac was collected from the southern Utah Paiute, though the date and the collector for this are unlisted.

It should be noted that the objects collected from the Chemehuevi by Isabel Kelly, discussed above, may also be considered Southern Paiute, since she described them as representative of both groups. Just as Whiting described the Havasupai trading creosote gum or lac to the Hopi, Kelly also recounts a story told to her by a Chemehuevi-Southern Paiute informant, Mataviam, about trading trips to the Hopi. He said a group of 8-10 people with two each from the Moapa Paiute, Las Vegas Paiute, Hualapai, and Chemehuevi would make a two-month trip to Hopi following rivers and streams. They brought with them creosote gum (lac), bows, buckskin, seeds, and food for their trip. In trade they brought back Hopi woven goods, including blankets, shirts, and belts. The informant said they did not wear these items themselves but saved them to trade for other goods since they were considered very high value. He also remarked that these trips happened before the white people came (Fowler and Garey-Sage 2016:205-206).

Dr. Edward Palmer, a naturalist and ethnobotanist, was another collector of lac and lac containing artifacts from the arid Southwest and farther south into Mexico. From the late 1860s into the early 1900s he collected biological and anthropological collections, identifying over a thousand new plant species, under the sponsorship of the Smithsonian, Harvard Peabody,

Harvard's Gray Herbarium, the U.S. Department of Agriculture, and others (Safford 1911; Bye 1979; Dexter 1990). He also collected from the Southern Paiute people. Dr. Putnam of the Harvard Peabody hired Palmer to collect in 1870 and again in 1875 when he was in St. George and Kanab, Utah and along the Muddy River (McVaugh 1956:68). According to Bye (1972:88) Palmer was the first major (non-indigenous) collector of botanical specimens in Utah, starting in 1870. His return trip in 1875 was funded by the Smithsonian as part of the mission to collect Southwestern archaeological objects for the Centennial. He collected a knife, now at Yale Peabody, that appears to be hafted with lac (YPM#ANT 005362). The catalog states the knife is from the Southern Paiute in southern Utah with no date given, though Palmer was known to be collecting in southern Utah for Harvard in 1875. He collected a stick with a ball of lac on the end, which the catalog card (PMAE#76-20-10/9422) calls "Gum of Sarrea mexicana" clearly a mistaken spelling for Larrea mexicana, indicating it is *T. larreae.* Bye also makes the important point that both Powell and Palmer arrived to collect material culture from the Southern Paiute at a time of transition between their traditional and acculturated way of life (Bye 1972:88).

In 1925, Mark Harrington was working for George G. Heye of the Museum of American Indian (which became the foundation of the National Museum of the American Indian, Smithsonian in 1989) doing fieldwork at Lovelock Cave in Nevada. Harrington collected several artifacts from the Moapa Paiute while in the area, among them two sets of dice, one made of tubular bones with red resin around their center (NMAI#14/1788) and a set of walnut shell dice filled with dark resin (NMAI#14/1787). The resin material in both sets of dice strongly resemble unheated and heated lac respectively. Harrington also collected a bag of crumbled lac off the stick (NMAI#14/1853) while with the Moapa Paiute, the catalog card calling it "pitch from creosote bush used as glue on arrowpoints." In 1924, Harrington also collected a fish spear with

dark resin coated bone points (NMAI#13/4096) from the Paviotso, or Northern Paiute, at Pyramid Lake and a ball of resin on a stick used as "cement" (NMAI#13/4193). These would require further analysis to be certain, but it may be lac adhesive.

Lower Colorado River

Cahuilla

The Cahuilla people live in Riverside County, south central California. There are nine Cahuilla reservations established by President Grant in 1865 that are grouped by location as Western or Pass Cahuilla, Mountain Cahuilla, and Desert Cahuilla (Kroeber 1908; Hooper 1920). Artifacts probably containing lac from the Morongo Band in the Pass Cahuilla region and the Torres-Martinez Band from the Desert Cahuilla region will be described below. Barrows (1900:48) in his ethnobotanical study of the Cahuilla, notes that a glue, called *san-ot*, was acquired from *Larrea mexicana (Larrea tridentata)* from the bark of the plant where amber colored gum was deposited by small scale insects. Barrows also mentions pine pitch, a gum from a milkweed plant and bitumen or asphaltum as other adhesives used by the Cahuilla. Bean and Saubel (1972:30) report that the Cahuilla, as described about the Owens Valley Paiute above, used a gum from a scale insect that deposited on the chamise plant (*Adenostoma fasciculatum)* to attach arrowheads and secure hopper baskets to mortars. This is probably the lac species *Tachardiella ferrisi.*

In 1907, Kroeber collected artifacts from the Cahuilla and published an ethnography the following year, where he discusses some of the objects. Kroeber describes a basket mortar which consists of a tray basket with no bottom adhered to a rock to catch the nuts, seeds, or other foodstuff after it is pulverized with a pestle. Kroeber says the common adhesive for joining the

basket to the rock in Southern California is asphaltum, but notes that the Banning Cahuilla (Morongo Reservation area) used a gum from a bush (Kroeber 1908:43). The object Kroeber refers to is in the Autry Museum (AMW#1-11106) with what appears to be lac smeared all over the base of the basket and the stone beneath it. Asphalt or bitumen is oily black in appearance and this resin is a dusky brown color instead, possibly indicating it is insect lac. Further analysis is required to be certain.

The Autry Museum also has two Cahuilla pottery vessels that may have lac components. One is a jar collected by Kroeber from the Cahuilla at Torres Reservation in Riverside County, California. A photo of the jar (AMW#1-10990) in Kroeber (1908:Pl.9) shows accretions on one side that strongly resemble lac repairs. Another large jar collected from a cave in Mission Creek Canyon in Riverside County (AMW#1-69175) appears to have a resinous sealant or repair material around the rim. There is also a rattle (AMW#1-11013) that Kroeber collected from the Torres-Martinez reservation that appears to have lac at the join between gourd and handle. There is a leather strip pasted over it, so further investigation is required.

Cocopah

The Cocopah people live in the southernmost lower Colorado River valley floodplains and delta in what is now the southwestern border of Arizona and northwestern Sonora, Mexico. Their lands were split up after the Treaty of Guadalupe, Hidalgo in 1848 and the people south of the border were called the Cucapá. Given the wetland conditions in the delta area, arrowweed (*Pluchea sericea*) is common in the local vegetation. In 1885, Edward Palmer collected bags of stick lac and crushed lac from the Cocopah (NMNH# E76146-0), and the catalog record called the material “gum of the arrowweed.” In 1884 or 1885, Edward Palmer also collected a plant

specimen of arrowweed identified as *Tessarea borealis* and *Pluchea borealis* (*Pluchea sericea*) for the NMNH Herbarium collection (# 93283), along with a flowering stem from the plant that was encrusted with *Tachardiella pustulata*. The handwritten notation on the Herbarium sheet states, "The lac which is found on the twigs is used by the Indians in waxing their bows and arrows, and for other purposes. This is caused by an insect *Carteria sp*., no. 5318 of the Entomology Dept., National Museum. F.V.C Riley March 19, 1892."

In 2006, Robert Bye, an ethnobotanist, and his associate J. Whitacre, added a notation to attach to the specimen, stating that the Cocopah used the gum of the plant to mend pots, among other things. They also provided the location where Palmer collected the specimen, at Municipio San Luis Rio Colorado, Lerdo (Antigua Colonia Lerdo) and the date range of December 21, 1884 to January 1, 1885, confirmed by (McVaugh 1956:177-178). Colonia Lerdo, now Lerdo, is approximately 13 miles south of Somerton, Arizona, where the Cocopah Reservation is located today. Lerdo was founded as a Mexican village in 1872 as an agricultural colony that was abandoned after 1896 (Gifford 1933:259). Others would collect artifacts with lac from Lerdo in years ahead.

Dr. Carl Lumholtz, a Norwegian naturalist and ethnographer, was funded to travel, collect, and document his observations in the arid Southwest. The AMNH funded many of Lumholtz's expeditions in the region, and those collections are housed there. One of those expeditions took place in northwestern Mexico in 1909 to 1910, about which Lumholtz published a book recounting the experience (Lumholtz 1912). One place Lumholtz visited and collected was Colonia Lerdo. While there Lumholtz collected a Cocopah rattle (AMNH# 50.1/4886). The gourd is attached to the handle with thick resin that appears to be lac. Lumholtz

(1912:250) noted that at the time of his visit to Lerdo, most of the Cocopah lived within Mexico where they farmed. He mentioned acquiring a bow while there, but not the rattle.

Edward W. Gifford, an ethnographer and at the time, Curator of the Museum of Anthropology at Berkeley, spent several seasons in the field with the Cocopah between 1916 and 1930, culminating in an ethnography of the Cocopah (Gifford 1933). In 1926 he collected a sample of lac from *Pluchea sericea* that was formed into a ball at the end of a stick, a glue application tool (PHM #3-2975). The catalog noted that it was collected from the Cocopah in lower Colorado river area, Baja or Sonora. Gifford mentioned Colonia Lerdo in his book but did not specify where the lac on a stick was collected. Gifford does mention the use of the lac adhesive and how it was processed (Gifford 1933:273):

> Adhesives. – No glue from fish heads, but gum from base certain arrowweed plants. Hardened rosin-like gum ground on metate, mixed with water, applied as glue. For broken pot, pieces warmed, glue applied with fingers; set when pot cooled. Not used on cooking vessel, as softens with heat. Used to attach rattle handle. Saw shaman tighten junction between these 2 parts of rattle. He held glowing stick close to gum on rattle, softening it, so he distributed it more evenly in joint by rubbing with finger.

Gifford also noted that arrowweed gum sometimes supplemented the repairs to pottery made with drill holes and string ties (1933:273). Further, in describing foot races, he says that the mesquite wood balls were sometimes coated with arrowweed "gum" and inlaid with shell beads (Gifford 1933:282). This style of kicking ball with bead inlay was also used by the O'odham as will be described later.

Two other examples of Cocopah lac use are represented by two more rattles. One was collected near La Grulla, c. 1944, collector unknown (PMAE# 44-54-20/15009). La Grulla is in Baja California south of Ensenada on the Pacific Coast. The rattle is a gourd with black painted designs, attached to a wood handle with a dark resin that appears to be lac. The other Cocopah

rattle (MOU#1990-8.1 AB) with an associated bag of creosote lac (*T. larreae*) are documented in a study of gourd rattles from the collections of what was then the San Diego Museum of Man, now the Museum of Us (Hector 2018:29) Given that the collections at the museum were not accessible to researchers during the time of this study, in person or online, this study was very helpful. This rattle was collected by Ralph Michelson in Baja California in the 1950s from the Cocopah who lived there.

Kumeyaay

The Kumeyaay people live along the southern border between California and Baja California, Mexico. Today they are divided into three groups, the Ipai, Tipai, and Kamia, with multiple bands and several reservations established from 1875 onward. The objects observed with lac in online collections are six rattles, four of which were collected at Campo in 1918 by Edward Davis for MAI (NMAI). The Campo Reservation is located about a mile north of the Mexican border and approximately nine miles east of Tecate. The earliest rattle was collected in 1881. One rattle was collected more recently, in 1951, in La Huerta de los Indios, from the Tipai-Ipai in Baja California.

Edward Gifford, in his ethnography of the Kamia of the Imperial Valley in California, described the use of gum (lac) from the "roots of certain old arrowweed plants" as glue for feathers on arrows, but not for adhering the point to the foreshaft (1931:28). He also affirmed that gourd rattles were attached to wooden handles with arrowweed gum (*Tachardiella pustulata*) (Gifford 1931:44). In her monograph of gourds rattles of Southern California, Hector reports on a Kumeyaay rattle formerly on exhibit at the San Diego Museum of Man (Museum of Us), and indicates the adhesive was "chamise pitch (creosote lac)" (Hector 2018:30). As

mentioned earlier, chamise is a common name for *Adenostoma fasciculatum*, which is a host plant for *Tachardiella ferrisi* and not *T. larreae*. Given that the early ethnographic sources all refer to Kumeyaay use of arrowweed "gum" and not creosote "gum", it is likely that the lac on this rattle is *T. ferrisi.*

Luiseño

The Luiseño live along the coastal area of southern California in San Diego County and inland in Riverside County and are now divided into six reservations. The people who lived along or close to the coast most likely used bitumen or asphaltum for adhesives. The inland Luiseño were more likely to make glue from pine pitch or, according to Kroeber (1925:651) a glue from a scale on the chamisal (chamise) *Adenostoma fasciculatum.* Sparkman concurred with these conclusions in his ethnography of the Luiseño (1908). He stated the most desirable adhesive, or gum, for making arrows was from "the greasewood [sic] *adenostoma fasciculatum* same shrub from which the foreshafts are made," adding later that that gum was caused by a scale insect (Sparkman 1908:205, 208). A Luiseño arrow collected by Sparkman in 1889 is now at the AMW (ID# 54.X.17), which probably has *T. ferrisi* lac adhesive, though the catalog record calls it pitch. In 1905, Constance Goddard Dubois, a novelist and amateur ethnologist, collected two Luiseño rattles, now at the AMNH (#'s 50/6118 & 50/6119). The adhesive at the join of both rattles do not appear black enough to be bitumen and may instead be the lac of *T. ferrisi*. Further analysis would be necessary to be certain of this material's origin.

Mojave

The Mojave, the northernmost Yuman-speaking people, live primarily in two areas. Fort Mojave is located in the tri-state area of southern Nevada, northwestern Arizona across to

Needles, California where the tribal headquarter is located. Fort Mojave was established in 1859. The second area is farther south along the Colorado River to the Colorado River Indian Tribes (CRIT) located in La Paz County, Arizona with headquarters in Parker, Arizona. Mojave lands also extend across the River into California. As previously described, the CRIT consist of a confederation of four tribes, the Mojave, Chemehuevi, Hopi, and Navajo (Stewart 1983).

Edward Palmer collected artifacts and lac specimens from the Mojave while on expeditions for the Smithsonian in 1870 and 1875. He also collected for the Harvard Peabody in 1875 and 1876. Two of the pottery vessels came from Fort Mojave and had lac sealant on the rims (Figure 39 A and C).

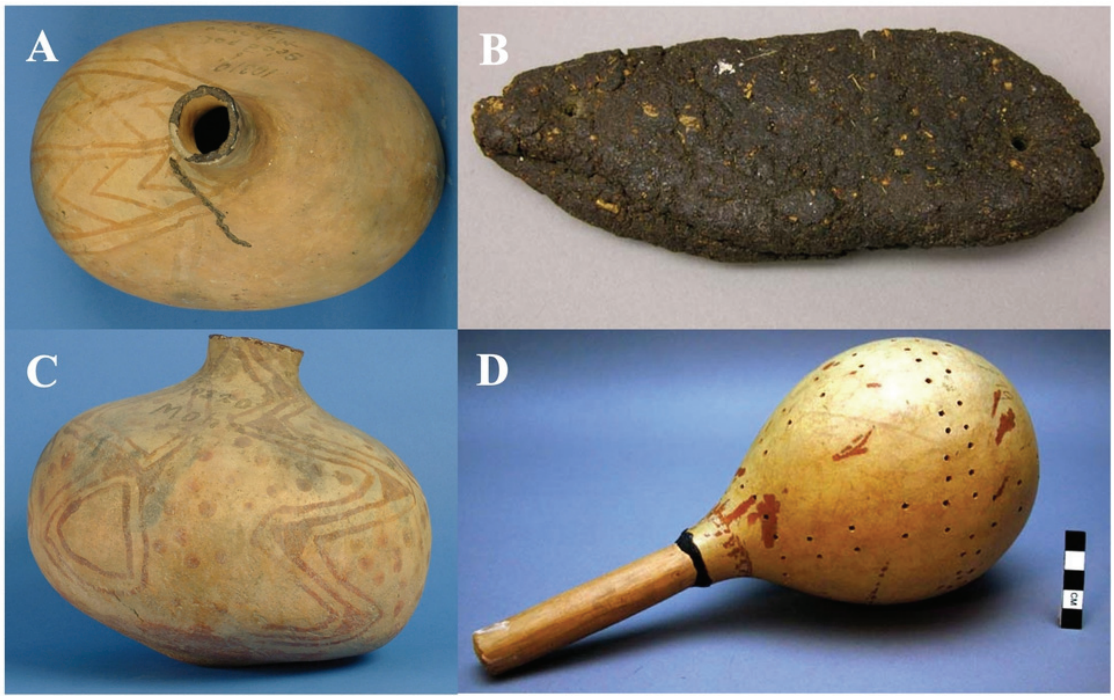

Figure 39 Mojave artifacts containing lac collected by Dr. Edward Palmer. **A** Mojave seed jar with lac sealant on the rim and lac repairs on the shoulder and body (NMNH#E10319-0) **B** "Prepared gum (lac resin) *Larrea mexicana* used when warm to mend pottery, baskets and as cement. Also used as septic" (PMAE#76-20-10/10083) **C** Mojave jar with lac sealant on rim (NMNH E10320-0) **D** Gourd rattle with lac resin for haft at handle (PMAE#76-20-10/10102). Images A and C are courtesy of Anthropological Collections Management, NMNH, Smithsonian Institution. Images B and D are from open access online catalog records, courtesy of the PMAE.

According to notes on the catalog record for the vessel in Figure 39A, an excerpt from Edward Palmer's field notes stated, "nearly every [Mojave] hut has more or less similar vessels for preserving seeds for use as food or for planting. . . A piece of crockery . . . is laid on top and . . . gum is put [a]round the edges to keep out air (Palmer 1870). On occasion, ceramic pots cracked; the Mohave mended and sealed them with a reddish, amber-colored resin Palmer recorded as Lamotea gum." The catalog note went on to explain that the gum was the lac resin from *Tachardiella larreae,* not the gum from the plant.

In their article on hermetic sealing, Euler and Jones (1956) conclude that most if not all indigenous people in the American Southwest from Basketmaker people in the north to the desert dwelling peoples in the south employed food storage technology to extend their harvests and/or gathered foods. In the north, people stored food in masonry or woven granaries or in pottery vessels sealed with clay stoppers and mud. In the south, the desert people also stored some foods in woven granaries but instead of sealing ceramic jars with clay they attached pieces of fired pottery and sealed it to as a lid with melted insect lac resin. Euler and Jones (1956) provide several examples of hermetic sealing with lac on pottery jars from a variety of Southwestern cultures over time, including Patayan and Hualapai, mentioned earlier, and Mojave, Lower Colorado River Tribes, and the Tohono O'odham, the last of which will be discussed in detail later. Euler and Jones note that the Mojave used lac (*Tachardiella larrea*) from the creosote bush *(Larrea tridentata*) on pottery and lac (*Tachardiella pustulata*) from arrowweed (*Pluchea sericea)* to seal gourd containers. They note that the Lower Colorado Tribe people also used lac from the arrowweed (Euler and Jones, 1956:90). They do not explain the reasons for using the different lacs for different storage receptacles, and it would be fascinating to find out. Perhaps one is stronger than the other or more pliable than the other.

Other early examples of lac containing objects collected from the Mojave people include a painted pottery scoop with lac repairs (NMNH # E22704-0) that was obtained in 1876 to a visit to the Hopi Pueblos by J.W. Powell. How it got to Hopi is unclear, but it was probably through trade. Kroeber (1955:2) in his monograph on Mojave pottery, also remarks on a jar he collected in 1908 (PHM# 1-13875) that: "The vessel has two mends or strengthenings [sic] with lumps of black gum."

A collection of sticklac called creosote gum (*Tachardiella larreae*) on creosote bush was donated to the Phoebe Hearst Museum in 1915 (PHM#1-19767) and had been collected by naturalist Mary Austin who, like Lumholtz, wrote with great appreciation of creosote bush and its resinous gum (Austin 1903:10):

> If you have any doubt about it, know that the desert begins with the creosote. This immortal shrub spreads down into Death Valley and up to the lower timber-line, odorous and medicinal as you might guess from the name, wandlike, with shining fretted foliage. Its vivid green is grateful to the eye in a wilderness of gray and greenish white shrubs. In the spring it exudes a resinous gum which the Indians of those parts know how to use with pulverized rock for cementing arrow points to shafts. Trust Indians not to miss any virtues of the plant world!

Several Mojave gourd rattles have been collected, the earliest two from Palmer in 1875 or 1876. Kroeber collected two rattles in 1904, now in the Phoebe Hearst collections. Edward Davis collected five rattles from the Mojave in 1920, four from Parker, AZ and one from Needles, CA, documenting the names of the Mojave owners and/or makers. He also mentioned they were made with the "gum of greasewood or arrowweed as were gourds that were sealed for storage" (NMAI catalog records 2022). Davis also collected a piece of molded lac resin (NMAI# 10/2730) which is shaped like a rolled cigar, unlike the flattened piece collected by Palmer.

In Leslie Spier's field notes (1931) and the book he published based on those notes (1955) he states the following regarding the Mojave use of gourds (1955:8):

> Gourds (axnalya), used for carrying water and storing seeds were of a variety of shapes: large globular gourds served for the storage of beans or seed corn, long ones to carry water, little round ones for rattles. Storage gourds were closed with a fitted clay disk, sealed with the gum (axpi'lyà) of greasewood and arrowweed. This was kept in a lump and melted with a firebrand on the spot where the gum was wanted as we use a soldering iron…The gourd rattle was globular, with a wooden handle inserted in the stem end but not extending through the opposite (bud end). The handle was fastened in with gum as described above.

All the Mojave gourds examined in museum catalog records and in publications with images in this assortment are very similar in appearance, with various globular gourds cut off near the base of the neck, stuck onto a wooden handle and set with a thick application of lac adhesive around the join on the exterior. Most of the gourds have small perforations in different patterns to improve the sound when shaken. A few of the more recent gourd sections are painted red overall.

Quechan

The Quechan lands are located along the Lower Colorado River above the Cocopah on the north side of Yuma, Arizona. As with other people who have lived along the river, they practiced agriculture and had surplus food like corn, beans, squash, and seeds to put away for storage. The Commanding Officer of Fort Yuma in 1853, Samuel P. Heintzelman, in describing how pottery vessels were made in his report, stated, “They seal up the seeds they wish to keep for planting in such vessels, covered with a fragment, and the edges closed with the gum from mesquite” (Heintzelman and Townsend 2008: 99). In his monograph on Yuman pottery, Rogers (1973:33) remarks that food storage ollas had small mouths so that they could be sealed with a disk and pitch, for long term preservation. Castetter and Bell, like Euler and Jones (1956) report that the Yuman people of the Lower Colorado River stored their food in small pottery ollas or gourds with a pottery lid sealed on with either the creosote bush or arrowweed gum and then covered it with straw (Castetter and Bell 1951:164).

While no examples of pottery with sealant on the rims were identified in online or in person examinations of collections, two rattles with lac adhesive and a collection of pieces sticklac were located, all at NMAI. Edward Davis collected one rattle (NMAI# 8/8629) in 1918 and in 1930 he donated 8 specimens of arrowweed gum on the stem (*Tachardiella pustulata*) on (*Pluchea sericea*), also collected from the Quechan. In his ethnography of the Yuma Indians, Forde (1931:130) explained that the handle for gourd rattles was fixed with arrowweed or mesquite gum. I believe people often mistakenly suggest mesquite gum was used as an adhesive because it shares the same dark color as lac and other exudate adhesives. Mesquite gum is a very weak polysaccharide compound that serves well as a paint and dye but wouldn't have the adhesion strength to secure a blade or point to an arrow or attach a lid to a vessel. Castetter and Bell (1951:116) explain gourd manufacture by the Yuman (Quechan) in greater detail below:

> For rattles the gourds were prepared by placing gravel or palm seed inside, inserting willow handle and sealed with heated arrowweed gum. The hard gummy or resinous material was gathered from the base of arrowweed bushes, mixed with water and applied as a sort of glue. This was softened by warming with a glowing stick after it had been applied, then smoothed by rubbing with a finger.

Finally, it is difficult to determine whether arrows have resin adhesives for hafting from online photos alone. However, Mason (1894:662) reports that most of the indigenous people in North America made arrows without any adhesive for hafting, but the people from the Southwest did, and the Shoshonean and Yuman peoples used an excellent gum from "Laria mexicana" as well as pine pitch and animal glue.

Sonoran Desert and Lower Inland River Valleys

Akimel O'odham and Piipaash

The Akimel O'odham people live along the middle Gila River, the lower Salt River, and environs in the Phoenix Basin of southern Arizona. They are consequently known as River People. The Akimel are divided into the Gila River Indian Community (GRIC), the Ak Chin Community, and the Salt River Pima-Maricopa Community (SRPMIC), which is comprised of Onk Akimel O'odham and Xalychidom Piipaash peoples. The Piipaash, formerly known as Maricopa, are included with the Akimel O'odham since they live amongst them in both GRIC and SRPMIC. The Piipaash once lived along the Colorado River with the other Yuman speaking tribes but migrated inland along the Gila River prior to Spanish arrival in the region (Harwell and Kelly 1983).

In the period from the 1870s to the early 1900s, anthropologists from the Bureau of American Ethnology, Smithsonian and American Museum of Natural History came to the region to document and collect the River People's material culture. Among the early artifacts collected were lac coated balls used by the Akimel O'odham in kicking races (Figure 40). Edward Palmer collected three of them in 1885 and Frank Russell collected two in 1901, all for the Smithsonian. Consequently, much was published about these objects in Smithsonian reports and related ethnographies. Culin (1907:671) describes the balls collected by Palmer and another ball, donated to the NMNH in 1877, as being covered by some vegetable material, probably a mesquite gum, calling them footballs. Culin also has an illustration of two Tohono O'odham "kicking ball players" and quotes others who described the balls as being made of the gum of greasewood and the gum of creosote, including Frank Russell (Culin 1907: 671).

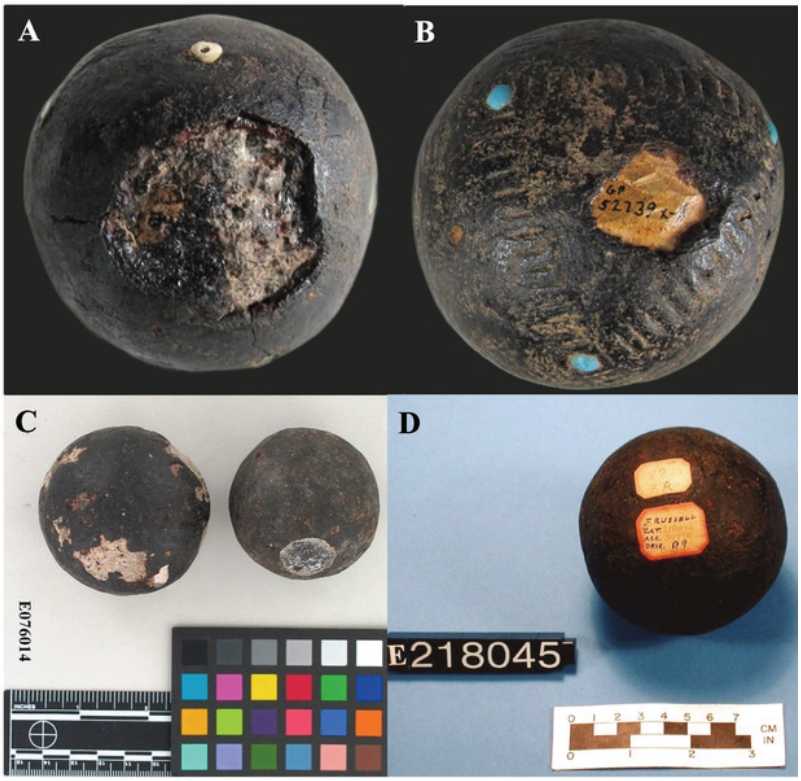

Figure 40 Akimel O'odham lac coated kicking balls **A** Stone ball with lac coating and shell inlay, collected in 1934 near Snaketown, AZ (ASM#GP-52739-X-3) **B** Wood ball with lac coating and glass bead inlay, collected in 1934 near Snaketown, AZ **C** Pair of stone gummed footballs collected by Edward Palmer in 1885 (NMNH#E76014-0) **D** Stone ball covered in gum (lac). Collected by Frank Russell, 1902 at the Gila River Reservation, AZ (NMNH# E218045-0) Images C & D are courtesy of Anthropological Collections Management, NMNH, Smithsonian Institution.

Frank Russell lived at Sacaton located in the Gila River Indian Reservation 1901-1902 to study among the Akimel O'odham (Russell 1908). He described the kicking ball races as intertribal contests between the Akimel and Tohono O'odham, or at that time, the Pima and Papago. He said that when the core of the ball is made of wood, either Mesquite or Palo Verde, it is larger, croquet ball sized, and covered with lac, "creosote gum." (Russell 1908:172) He noted that the stone balls tend to be smaller in diameter, covered with the same gum (lac). He stated that the runners told him they could go faster when kicking the ball with lac rather than without. He also suggested that their connection to Hohokam balls found in nearby ruins may have

imbued them with significance and power for the Akimel (Russell 1908: 173). Bahr (1983:191) has an illustration of the balls collected by Palmer and a photograph of one of the footraces in action. Bahr suggested that the O'odham preferred to run using a kicking ball to keep their pacing during long distance trips of twenty or more miles, and for race preparation.

According to the catalog card for the collection of two of the balls collected by Palmer (NMNH# 76014), one was sent to the botanist Dr. Volney Jones in Michigan. Dr. Jones, as mentioned in Chapter 3, was the botanist who identified the resin used in turquoise inlay objects from Ridge Ruin as being lac. Though the catalog for the ball doesn't mention the results, it is highly probable he identified the coating on the ball as lac. Dr. Christina Bisulca was permitted to sample the coating from one of the same balls and another (NMNH# E218045-0) collected by Russell and confirmed the identification by FTIR analysis of the coatings as insect lac exudate for both (Bisulca 2019). In addition, I analyzed samples from the two balls illustrated in Figure 40 A and B, (ASM#GP-52739-X-3 and ASM#GP-52739-X-5) and the coating for both of them is also insect lac (as described in Chapter 7).

Other Akimel O'odham object types with lac components were an assortment of arrows collected by W.J. McGee in 1894 with lac for hafting adhesive confirmed by analysis (Bisulca 2019), though it was cataloged as being cemented with mesquite gum. Several basket weaving awls with lac handles; pottery with lac repairs; and samples of raw lac material were also found in museum collections. Both Frank Russell and Mary Louis Kissell collected lac handled awls while working on their ethnographies. The handle on the awl from Russell (NMNH# E218084-0) was confirmed as lac exudate by Dr. Bisulca (2019). Russell (1908:106) reported that the metal points of the awls were repurposed umbrella ribs, and that handles were made of mesquite wood and balls of creosote gum. He has illustrations of both types.

Castetter and Bell (1942:215) reported that in growing tobacco, the Akimel O'odham would gather the seed from the best plants and store them in gourds sealed with "the gummy secretion of the creosote bush" and then store the gourds in the ground for future use. Though the gourds shown in Figure 41 are from the Pima Bajo area of Sonora, Mexico and came from an archaeological cave site, they were found filled with seeds, still unidentified, and have lac sealant around all their rims. The Akimel O'odham seed filled gourds would probably appear the same.

Figure 41 A collection of four gourd containers found full of seeds and sealed with lac, Prehistoric, Rio Sonora Province, Sierra de la Gallina, Sonora Mexico (ASM#s A-3391-X-1, A-3392-X-1, A-3393-X-1, A-3394-X-1).

Kissell was doing fieldwork in several villages of both the Akimel O'odham and Tohono O'odham people in 1910 and 1911 for the American Museum of Natural History, investigating basket weaving and collected lac handled awls from both. She collected one awl from the Akimel O'odham (AMNH 50.1/ 5270) from Sweetwater Village, Gila River Indian Reservation. Like Russell she reported that the point was made of metal umbrella ribs or nails, but in prior to using modern materials they used cactus spines, bone, or wood. She described the differences

between the awl types of both peoples at the time she collected (Kissell 1916:203, 206) as follows:

> Papago handles are of mesquite wood, or old broom handles; Pima are of willow, cottonwood, mesquite wood, mesquite root, or some old tool handle. The material for gum handles is the secretion of a tiny insect (*Carteria larreae*), found upon the greasewood twigs. This twig bearing the secretion is broken off, held over the fire until the gum is softened, and then shaped with the fingers about the end of the steel, when, with cooling, the gum becomes hard like wood (Figure 49b). Another gum less frequently used is creosote (*Covillea tridentata*, or *Larrea Mexicano*).

Figure 49 in Kissell's report (1916) has illustrations of various awls and cutting tools used in basket weaving. Curiously, the lac scale insect she mentions is the same but an older name for, *Tachardiella larreae*, which does live on *Larrea tridentata*, not greasewood. This is an excellent example of the confusion over nomenclature of the species involved.

Kissell collected four stems of *T. larreae* on creosote bush stems from San Xavier, a Tohono O'odham village (AMNH # 50.1/ 5154), referring to it only as "red coloring material." Lac from Asia was used as a textile dye for centuries, but the use of *Tachardiella sp.* has not been found mentioned so far as a dye material. Kissell's assertion piques interest to investigate further. Russell collected a bag of sticklac (NMNH# E217981-0) from the Gila River Indian Reservation calling it creosote bush gum. The catalog card indexed it as gum-cement used for mending. Russell (1908:131) reported that "pottery was mended with the gum from the creosote bush, Larrea mexicana." Russell also collected a ball of molded lac in Sacaton in 1901, confirmed by FTIR analysis (Bisulca 2019), that the catalog card described as Palo Verde gum, used for mending.

Edward Davis collected an Akimel O'odham pottery jar (NMAI # 8/9264) from Blackwater Village on the Gila River Indian Reservation in 1919 with a hole near the base that appears to be repaired with lac resin. There is an olla in the ASM pottery collections (ASM#E-

3474) dated to 1900 that also has a hole filled with resin, identified as lac through FTIR analysis. Though no Akimel O'odham pottery vessels with lac sealant have been found while searching online or in person, its use has been reported. Ezell (1961:40) states:

> This sealing was probably done by smearing the mouth of a jar having a relatively narrow opening with lac, the encrustations of the lac insect found on the creosote bush, and pressing a potsherd shaped to fit down on the soft gum. If the job were properly done a nearly air-tight
> closure could be obtained.

In 1930, Leslie Spier began field work with the Piipaash living along the Gila River. Regarding mending pottery, he wrote in his field notes, "Reddish lumps of sap exuding from the base of the arrowweed is rubbed into the crack of a broken pot while still hot to repair it" (Spier 1931:19). He also noted that only lac from the arrowweed (*Tachardiella pustulata)* was used to mend pottery (1933: 108). Regarding Piipaash kicking balls, Spier wrote in his field notebook (1929:25):

> the gum exuded from a plant (medicinal plant collected) and gum at base of arrowweed is melted on a piece of broken pottery. They dip a stone, 1½" diameter in this until a ball was formed, about size of a baseball. The two good runners would stand and at signal would kick it off and race with it. They always race to a point and return. This was thrown with the foot, not kicked along the ground. The best kicking stick runner was pitted against the best of the Pima. Bet heavily on this.

A Piipaash vessel collected from the Gila River Indian Reservation, its date and collector unknown, is in the collection of Yale Peabody Museum (YPM# ANT 019118). The catalog record, which noted the jar should be sealed with a pottery disc lid, stated the jar was used for saguaro wine, or it may have been for storage of a related product, saguaro syrup. Castetter and Bell (1937:14) describe the process of making saguaro syrup below:

> The liquid drained off was placed on the fire and cooked to a syrup, this being set aside from day to day. When the whole quantity was at hand it was sealed in a jar made air-tight by cementing a pot sherd over its mouth with adobe mixed with

> fine grass or a transparent yellowish-brown "gum," produced' by a scale insect (*Tachardiella fulgens*) on samo prieto (*Coursetia glandulosa*).

This is the first time *T. fulgens* has been noted as a cultural material in the ethnographic literature reviewed thus far. A Piipaash decorated and glazed plate (ASM #22608), collected by Laveen in 1900, is a type that Russell (1908:130) suggested was made for trade. It has several small lac repairs around the rim, confirmed with FTIR and UV light. A Piipaash rattle from the Yale Peabody (YPM#ANT 019064), collected from the Gila River Indian Reservation, again date and collector unknown, was reported to be made with arrowweed gum (*Tachardiella pustulata*). Lastly, an adhesive on a Piipaash arrow shaft (ASM #E-3086-X-8) has been analyzed and identified as insect lac.

Lac and Akimel O'odham Creation Story

Variations of the Akimel O'odham creation stories have been translated and published many times over the years, a selection of them referenced here (Russell 1908; Lloyd 1911; Lumholtz 1912; Crosswhite 1981; Nabhan 1985; Teague 1993; Bahr et al., 1994; Rea 1997; Bahr 2001; Loendorf and Lewis 2017; Martinez 2019). There are two stories recounted in all of them, one about the Creation and another about the Flood, that contain specific references to the greasewood bush (creosote bush) and the associated gum (lac) made by insects. In the creation story, the creosote bush, called greasewood in older editions, is the first plant created by the Earth Doctor (Earth Magician in some accounts) out of the void and darkness. The second thing he created, according to Bahr et al. (2004:54) were "little tiny ants to live on that bush, on its gum that comes out of the stem." Crosswhite (1981:47) reported that those insects, called *tcotcik tâtâny,* produced a black gum on the bush, *shegoi,* the O'odham name for *Larrea tridentata.*

Nabhan (1985:11) relays that the insect that came from the greasewood was "a tiny, scaly insect that could use the resin of the greasewood to produce its own covering of lac" later implying the lac became the crust of the earth and the material that became mountains. Other early creation narratives included the supernatural beings or deities called Elder Brother and Coyote (Loendorf and Lewis 2017).

In the Flood story, after the world and its inhabitants had been created, there is a cycle of destruction from cataclysmic flooding caused by Earth Doctor, followed by a cycle of recreation by the Earth Doctor, Elder Brother and Coyote. The Tohono O'odham refer to Elder Brother as *I'itoi* and the Akimel O'odham call him *Siuuhu* (Underhill 1938; Teague 1993). According to Rea (1997:140) *I'itoi*, or Elder Brother, makes himself a huge olla out of *shegoi ushabi,* the O'odham name for the creosote bush "sap" (*Tachardiella larreae*), in which to take shelter to survive the flood. Before Elder Brother gets into the vessel, he puts all the seeds and things from the world inside and then seals himself by starting a fire to seal up the jar (Lloyd 1911:41). Once the floods receded, Elder Brother had to wait for the world to dry out and warm up to be able to unseal his olla and get on with recreating humans and rest of earth's living things (Lloyd 1911:43).

If the interpretation that the gum in the stories is lac, as suggested by Lloyd (1911), Crosswhite (1981), Nabhan (1985), Rea (1997) is accepted, it would reveal a significance of lac to the Akimel O'odham far beyond the mundane. Although they don't mention the role of lac in the origin story, Loendorf and Lewis (2017) argued the creation story is perhaps more than a metaphor, relating to past river downcutting events impacting irrigation and livelihood, contributing to cultural material transitions between the Preclassic and Classic Hohokam periods, and again in the Protohistoric to Historic eras for the Akimel O'odham. Their study concludes

with the assertion that the Akimel O'odham are direct descendants of the Hohokam, that the continuity is there in the material culture, but also in the adaptation expressed over time during cycles of disruption. There is certainly material culture continuity between the Hohokam and Akimel O'odham in the use of lac in hafting arrowheads to foreshafts, in awl handles (Haury 1950:377-378) and in coated balls (see Figures 30 and 40). Perhaps with future investigation there will be further discovery of Hohokam pottery with lac repairs or sealant, besides the one example from Ventana Cave mentioned in Chapter 3. One archaeological jar (see Figure 42 below) was collected by Carl Lumholtz for AMNH that might be of Hohokam origin. The shape of the vessel resembles other Hohokam jars, but the surfaces are eroded and undistinguishable. What is noticeable though, is the huge smear of lac resin down one side. Given the thickness and continuity of the repair compared to the highly eroded surface of the vessel, it is possible the native repair is far more recent than the pot. So far, no mention of the vessel has been found in Lumholtz's publications or in publications from AMNH to provide further clarity as to its origin.

Figure 42 Archaeological pottery vessel with large lac repair, culture undetermined. Collected in 1911 by Carl Lumholtz, town of Pima, Graham County, Arizona. AMNH (#29.0/1602). Catalog image courtesy of AMNH.

Tohono O'odham

The Tohono O'odham people live in a large area of south-central Arizona in eleven districts, bordering Mexico on the south, near Tucson on the east, near Casa Grande on the north and near Ajo on the west. The smaller non-continuous segments are San Xavier, south of Tucson; San Lucy District near Gila Bend; and Florence Village. The Tohono O'odham are known as the Desert People. The Tohono O'odham, like many of the groups discussed above, used lac to make arrows, to repair and seal pottery, and to make awls for basket weaving. Out of the 49 Tohono O'odham objects found containing lac, both in person and online, more than half of them are pottery vessels with lac repairs. Twenty-six of those vessels are in the collections of the Arizona State Museum and were examined, analyzed, and confirmed as lac in person, as part of the Save Americas Treasures pottery project in the early 2000s, and more recently as part of this research (see Chapter 7). Those pots range in dates from 1880 to 1970.

W.J. McGee and an assistant came to the Papagueria in 1894 exploring and collecting for the Bureau of American Ethnology (BAE) in southern Arizona and down into Sonora, Mexico (McGee 1896). They collected dozens of pots from the Tohono O'odham at San Xavier that are now in the NMNH, but sadly they have no catalog photographs, and the catalog records have little detail. Lumholtz and Kissell extended their research and collecting for AMNH with the Akimel O'odham, described above, to Tohono O'odham lands the same year. Kissell collected Tohono O'odham basket weaving awls and raw stick lac from Santa Rosa and San Xavier, now at AMNH and described and illustrated in her book (1916:203, 205, Figure 49), noting that the knives were probably made by the weaver with repurposed blades and handles of gum (lac). Besides collecting raw lac on stems as a coloring material, mentioned above, Kissell also

collected *Tachardiella larreae* on *Larrea tridentata* stems at Santa Rosa, in the Gu Achi district, calling it the gum used to make awl handles (AMNH# 50.1/ 5243).

Of Tohono O'odham uses of lac, Lumholtz (1912: 223) reported the following, while extoling on the virtues of *Larrea tridentata*:

> The secretions of a scale insect carteria, which are deposited on the branches of this bush, serve the Papago for several purposes. Handles for the awls which the women employ in the manufacture of baskets are of this material, which is first dried in the sun and ground, then heated on a piece of crockery over the fire, and moulded into shape. Also balls for the foot-races are made from it, a stone being placed inside. Besides it serves for mending pottery. The greasewood is as hardy as the cactus and the hardiest of all the trees or bushes of the desert. It contents itself with poor soil if necessary, but it attains its finest development on the rich detritus of the llanos. … To me the greasewood is a symbol for health and an example of cheerful existence under adverse circumstances. It gives out an odor which it would be impossible to count among the perfumes of the world and which suggested the name creosote bush contemptuously applied to it.

Lumholtz also collected awls and a knife with lac handles for AMNH, two awls and a knife from San Xavier and one awl from Krilipat Vaaka village, which may be misspelled on the catalog record. It could possibly be *A-at'kam Va-aki*, the Akimel O'odham name for Sandy Ancient House according to Teague (1993:246), but it is not certain. Lumholtz also collected a large bundle of sticklac stems (AMNH# 50.1/4664), *T. larreae* on *Larrea tridentata*, that the catalog record calls greasewood gum, gum for pot mending.

The collections found with lac at the NMAI are all pots collected by Davis in 1910 and 1919, plus a wood stick with a wad of lac on top for applying the lac to broken pottery (NMAI #8/9830) collected in Santa Rosa, Gu Achi district. Figure 43 shows one of the repaired vessels that Davis collected, and two lac applicator sticks, plus other Tohono O'odham pots with lac repairs at ASM, showing a range of repair types.

Figure 43 Variation in Tohono O'odham lac pottery repairs and lac application tools. **A** Painted olla c. 1939 with lac crack repair (ASM#2005-666-46) **B** Jar from Flat Yellow Mountain with hole plugged with lac, and detail of repair (ASM#E-2504) **C** Redware jar with a lac hole plug on the left and a large lac adhered patch on the right. Collected by Davis at Ali Chukson in 1919, (NMAI#8/9724) **D** "Gum from creosote bush, on end of stick, for mending pottery" collected by Edward Davis in Santa Rosa, 1919 (NMAI# 8/9830) **E** Saguaro rib handle with lac, applicator stick from a storage shelter at Santa Rosa Wash, collected by Julian Hayden in 1942 (ASM#A-3710).

Fontana et al. (1963: 81) in their book on Papago Pottery recounted:

> If a pot should chip, crack or have a small piece broken out of the rim or a hole, it may be mended by the user. For this purpose the Papagos used lac gathered from the stems of the creosote bush *Larrea tridentata* sometimes called greasewood, found so abundantly in their desert region. Lac is produced by a minute insect *Tachardiella larrea* and Papagos boil a preparation of this red material to make a black binding glue…Unhappily we were never able to see glue being prepared and applied to pottery … We found no other instance of any other glue being used for pottery mending.

Based on an interview in 2007 with Joseph Joaquin, former Tribal Council Representative for the Sells District and Cultural Resource Specialist for the Tohono O'odham Nation for many years, Shackle et al. (2009: 27) related that Mr. Joaquin said "not all creosote bushes have it. You have to really look for it. When you find it the whole bush has got it. But it's spotted here and there" As one who has now spent several years scouring creosote bushes in the Tucson area for lac, I can attest it is not easy to find. As to the use of lac as pottery repair material, Joaquin said:

> You grind it up. Add water and heat it. You add different amounts of water to get the desired consistency. Then you clean the area of repair on the pot and slap it on… its still in use, you know, especially on the western side where things and that are still carried on the way they're supposed to be.

Finally, Joaquin confirmed that the jar *I'itoi* made, "the jar he sat in and floated around" to survive the flood recounted in the Akimel O'odham creation story earlier, that lac was sealed with lac (Shackle et al., 2009: 27).

Among all the historic era Tohono O'odham and Akimel O'odham pottery observed in person and online, none has had visible evidence of lac sealant present. Sullivan reports that the Papago stored "agave, leguminous seeds, mistletoe berries, prickly pear pulp, pumpkin rind, roots, sahuaro products (pulp, seeds, syrup), and yucca in lac sealed jars" (1983:320). Several ethnologists have reported on the Tohono O'odham practice of sealing jars with saguaro syrup, not only for their own use and gifts but as a major trade item with the Akimel O'odham and perhaps others (Russell 1908; Underhill 1939; Crosswhite 1981). Palmer (1871: 417) described the sealed jars as follows:

> The Papajo [sic] Indians, in transporting earthen vessels filled with sirup or preserves made of this fruit to market, cover their jars with a thick coating of mud, which renders them less liable to break in handling, and at the same time keeps the contents cool, and prevents evaporation, the crockery used being very porous.

The monograph on the giant cacti of Arizona is more exact in its description of the sealant (Thackery and Leding 1929:412):

> The portion to be kept for future use is placed in ollas and sealed tight, the seal being accomplished with a piece of broken pottery chipped into a circular form to fit the mouth of the olla. This crudely constructed cover is held in place by a preparation either of adobe mud mixed with fine grass or a transparent yellowish brown gum or lac gathered from the "Samo prieto" (*Coursetia glandulosa*) upon which it is produced by a scale insect (*Tachardiella fulgens*). When properly put up in this manner the syrup or preserve will keep more than a year.

Others, (Castetter and Underhill 1935:21; Castetter and Bell 1937:14) repeated and referenced

Thackery and Leding above.

Regarding rattles and other objects where lac was applied as an adhesive, Castetter and Bell (1942:201) report that the Tohono O'odham used the "gummy secretion of creosote bush or arrowweed" to secure the handle to the gourd. Castetter and Underhill (1935:71) state that arrows are hafted with the plant resin from brittlebush (*Encelia farinosa*) since mesquite gum melted in the heat and creosote gum (lac) was too sticky, making the passage of an arrow through grass problematic. It should be noted that the only material found through FTIR analysis of O'odham arrow adhesives was insect lac.

State of Chihuahua, Mexico

Tarahumara

The Tarahumara live in the Sierra Madres Occidental, in Chihuahua, Mexico. Their communities range between the uplands, which have a higher elevation pine forest ecosystem, and the canyons or barrancas, which have an oak woodland to tropical ecosystem, depending on elevation. In the 1000- to 1300-meter elevation range, *Coursetia glandulosa* grows, from which *Tachardiella fulgens* is obtained, along with other short trees and shrubs (Bye 1976). While the Tarahumara have used lac like many of the other people described above, as an adhesive to make object like arrows and rattles, and to repair pottery, they are the only people found to date who primarily use insect lac as food.

Carl Lumholtz visited the Tarahumara people in the early 1890's during his five-year expedition into Mexico (Lumholtz 1902). While there he collected more than two hundred artifacts for AMNH, including one gourd rattle from Carichí, which appears to be joined with lac resin (AMNH# 65/833). He, and later Pennington (1963:215), noted that the glues used on musical instruments for fabricating and repair came from plant roots, that is plant starches,

including from a lily plant. The adhesive on the gourd above is clearly resin, not starch, and is possibly made of lac. During the same period, Lumholtz deposited more than two hundred Tarahumara artifacts at the Field Museum in Chicago. Sadly, most of those objects do not have catalog photos, but one object did, called a “stick of aphid secretion”, which is instead a processed roll of *Tachardiella fulgens* lac, which the Tarahumara call *arí*. (See Figure 44D). Another visitor and collector to the Tarahumara in the 1890s was Dr. William Pepper, who was a physician and Provost of the University of Pennsylvania. Among what he collected from the Tarahumara were medicinal herbs. He called this lac specimen "Aree.” The catalog record says it is an “Indian food. A solid secretion of a plant louse.”

Figure 44 Tarahumara lac, *Arí*, processed and unprocessed, for food
A Photo of processed *Arí*, (Bye 2016). **B** Sticklac, *Tachardiella fulgens*, collected in the barrancas by Dr. William Pepper, 1894 (UPENN#17356) **C** Sticklac, *Arí*, for sale at medicinal plant market in Chihuahua (Bye 2016). **D** Processed lac, called aphid secretion, collected by Lumholtz in 1890s (FMNH# 48485).

In 1930, Wendell Bennett and Robert Zingg went to Tarahumara country as graduate students at the University of Chicago, collected artifacts (now at the Milwaukee Public Museum) and wrote an ethnography (Bennett and Zingg 1935). In their book, Bennett and Zingg (1935:130-133) describe the lac used by the Tarahumara. They quote extensively from Standley (1920) who writes about *Llavein axin axin,* the fat, not lac, producing scale insect used to make

laca or maque (see Chapter 1). The confusion comes from the common name for lac in Tarahumara, which is *arí* but also sometimes *aje*, which is the common name for the scale fat used to varnish gourds and wood. Later, in a description of *Coursetia glandulosa* (1935:170), they get it right and note it is the host plant for insect lac.

Bennett and Zingg (1935:145, 157, 158) describe the trade of lac as a commodity in the context of food production, which is interesting. The lowland Tarahumara who lived in the barrancas practiced terrace farming, growing onions, garlic and chiles, and harvested agave hearts, and lac scale (*arí*). They traded those products along with blankets and baskets they wove with other Tarahumara who lived up in the highlands for the produce they grew, such as corn. The lac was mixed with salt and chilepequín, which they grew, and used as a condiment, and as a remedy for colds and headaches (Bye 1976:88). They mixed it with water and drank it as a remedy for hangovers after drinking *tesgüino* (corn beer). It was expensive though, so only the wealthy could afford to buy it (Bennett and Zingg 1935:147). Highlanders would trade a decaliter of corn for one cup of *arí* (1935:158). Bennet and Zingg reported that Palmer said Goma de Sonora, the Spanish name for *arí*, was mixed with water and used for colds and fevers, selling to pharmacies for a peso a pound. A website from Radio Fama in Mexico has a blog posting about Chihuahuan gastronomy and the contemporary use of Tarahumaran *arí*. The article says the cost is still high, "if you buy in the mountains you can get it at 70 pesos but in the city often quoted up to 1200 pesos" (Notifama Informacion Estatal 2012). According to Irigoyen-Rascón and Paredes (2015:163) the condiment made of lac was also added to water to make a sauce for food, and the raw lac and lac processed into cakes wrapped in plastic may be found in markets in Guachochi and Batopilas. They also mention that the lac is still used for various medicinal purposes. Historic examples of the medicinal use of lac are described in Chapter 3.

Robert Bye, an ethnobotanist who has spent years studying the plants used by the Tarahumara, suggested the term *arí* came from the Pima Bajo and Ópata from the west through trade and from incursions into their neighbors' territories (Bye 2016). He reports that the lac used by the Tarahumara is *Tachardiella fulgens*, (*arí*) which lives on *Coursetia glandulosa (samo)* and that the scale is tended by various possible species of ants (*sikui)* in a tri-trophic mutualistic relationship. He adds that the Tarahumara awareness of this ant-plant-scale insect relationship indicates cultural-based indigenous knowledge (Bye 2016). Bye also states that the Tarahumara used *arí* to repair *tesgüino* pottery, which is considered sacred.

The Arizona State Museum has a large Tarahumara jar collected by Edward Faubert in 1958 in Labarachi, Chihuahua, which has both pine pitch and lac repairs as well as slats of wood with cordage ties for reinforcement (ASM#1977-33-270). The National Museum of American Indian also has a large Tarahumara jar laced with thongs with a resin repair on one side that resembles insect lac. It was collected in Batopilas, Chihuahua (NMAI# 25/2678). Litzinger (1984:111) also noted the Tarahumara used lac as pottery repair.

State of Sonora, Mexico

Pima Bajo

The Pima Bajo people lived in the Sierra Madre mountains between the states of Sonora and Chihuahua, traditionally. The people were in three groups geographically, the Ures, Nevomes and Yecoras (Hinton 1959). They are mostly acculturated into Mexican society today (Hinton 2021). In the past when pascola and matachin dances were still performed, the Pima Bajo used lac as an adhesive to make rattles for the ceremonies. There are three rattles from the Nevome band of Pima Bajo at the NMAI, collected in 1924 by Edward Davis in Ónavas Municipality. The shapes of two of the three gourds resemble Yaqui rattles more than those of

the Akimel O'odham or Tohono O'odham. The dark resin adhesive is clearly visible between the bottom of the gourd and the handle, and it strongly resembles insect lac. The third rattle is rounder and painted in red, black and green, but again the resin adhesive is quite visible and strongly resembles lac.

Mayo

The Mayo people lived along the Mayo River and Fuerte River valleys south of Yaqui lands. Today the Mayo live in dispersed villages along the coast down into Sinaloa and inland (Yetman and Van Devender 2002). The Mayo have medicinal uses of lac (*Tachardiella coursetiae*) [sic](*fulgens*) where they boil the lac in water with cinnamon, and mistletoe gathered from mesquite, making a tea to treat children who get diarrhea from their mother's milk (Yetman and Van Devender 2002:198). While no Mayo artifacts have yet been found in museum collections that may contain lac, a photograph of a pair of rattles (*sonajas*) in Yetman and Van Devender (2002:150) appears to have a lac adhesive on the rattle on the left, but the photo is black and white and it is difficult to be certain.

Yaqui

The Yaqui lived in Sonora, Mexico, south of Guaymas, along the Rio Yaqui in villages from the coast and inland. After the 1880s, due to conflict with Mexicans, and later deportations, the Yaqui began dispersing, in some cases moving into Arizona, settling into communities along the Southern Pacific Railroad, including in a village called Pascua, then just outside Tucson (Spicer, 1984; Sheridan 1996b). Though acculturated by the Spanish since the 1600s, the Yaqui endured, as Sheridan noted (1996b) by fusing their traditional lives and beliefs with the new

cultures that surrounded them. The Easter ceremonies still practiced by the Yaqui today in Arizona are an example of that fusion. Painter et al. (2019: 171) describe the ceremonies and the associated use of gourds in the Matachine dances, noting, "the gourd rattles is called *ayam*…It is treated inside with hot glue to strengthen it and to sharpen the sound." Painter never clarifies the source of the hot glue, nor do any others who have written extensively of the Yaqui. However, the rattles themselves answer the question.

Edward Davis, the collector for the Museum of the American Indian (NMAI) who seemed to be ubiquitous in the arid Southwest, collected two rattles from Pascua (now called Old Pascua in Tucson city limits), in 1921. Both rattles were used in the Matachine dances as part of the Easter ceremonies. Both rattles (NMAI#10/6496 and #10/6497) have visible adhesive between the handle and gourd that strongly resembles insect lac. I examined a Yaqui arrow, collected in 1953, hafted with resin that resembles lac at the Amerind Museum (AFM#1861) and analyzed the resin and paint on another Yaqui arrow (ASM# 23106-X-23) collected in Cummings era (1915-1938), location unknown. It could have been collected in Tucson or in Sonora. The adhesive and paint are lac, as indicated by FTIR and UV analysis.

Summary and Conclusions

The examination and analysis of artifacts containing lac from an arid Southwestern historical context, both in person and online, culminated in 212 manufactured objects and 15 ethnobotanical specimens, collected from 20 cultural groups. These groups ranged from southern Nevada, southern Utah, eastern and southern California, Arizona, Sonora, and Chihuahua. The total number of objects with lac by cultural groups are shown in Figure 45 and the number of objects by object type and cultures from whom they were collected are in Table 13. Of the 227

artifacts and ethnobotanical specimens, 149 of them contain lac with certainty, 41 probably contain lac and 37 possibly contain lac, the latter two groups requiring further examination and analysis to gain certitude.

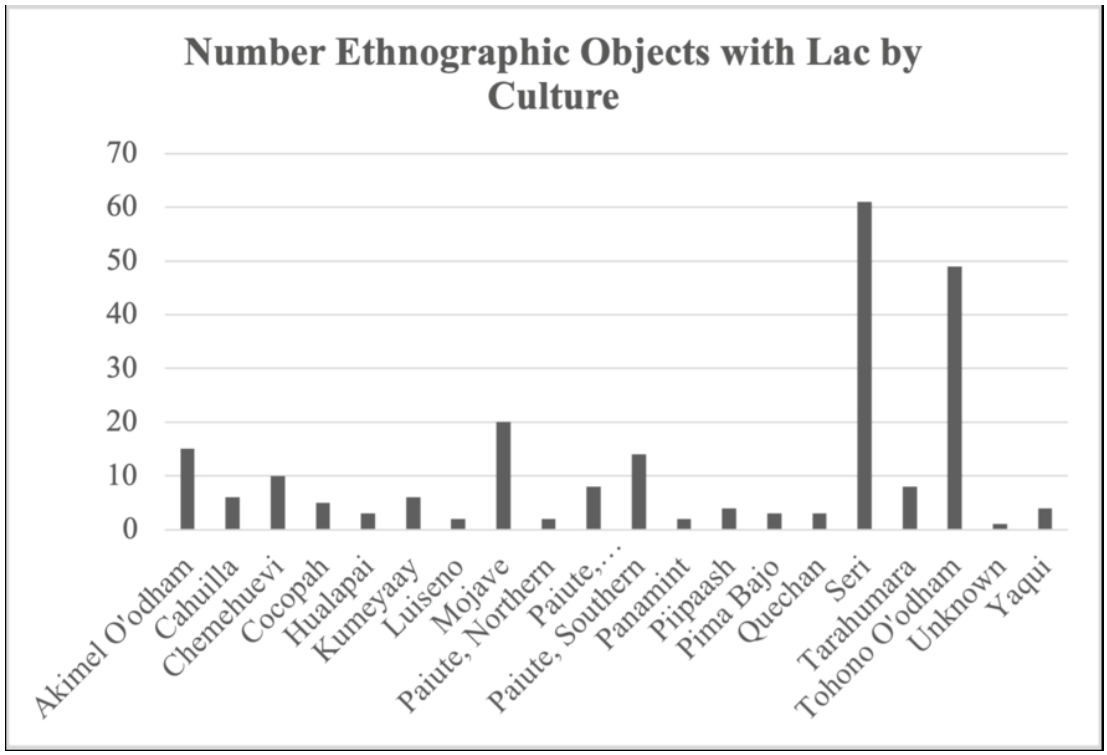

Figure 45 Chart of the number of ethnographic objects with lac by culture

The Seri (Comcáac) have the most artifacts with lac the cultural group listed in Figure 45 and will be discussed in detail in Chapter 5. It must be noted that the numbers of objects don't necessarily reflect the amount of lac used by a particular people, as much as the collecting bias of museums. So many of these collections were made as part of expeditions funded for the capturing of cultures thought to be declining to extinction. Some people in Sonora like the Seri were studied intensively while other groups farther inland were more dispersed or were considered too acculturated and consequently received less attention.

Another way to examine the distribution of object types is by culture first with the number of artifact types for each group in Table 14. Over 68% of the objects are represented

Table 13: Number of Ethnographic artifacts found containing lac by culture

Object Types	Number	Cultures
Amulet	9	Seri
Arrow	20	Akimel O'odham, Chemehuevi, Piipaash, Seri, S. Paiute, Tohono O'odham, Yaqui
Awl	12	Akimel O'odham, S. Paiute/ Chemehuevi, Panamint, Tohono O'odham
Ball, lac coated	7	Akimel O'odham, Mojave
Carving, wood	21	Seri
Dice	2	S. Paiute
Rattle	43	Cahuilla, Chemehuevi, Cocopah, Hualapai, Kumeyaay, Luiseno, Mojave, Pima Bajo, Piipaash, Quechan, Tarahumara, Tohono O'odham, S. Paiute/Chemehuevi, Yaqui
Harpoon	7	Seri
Pottery	55	Akimel O'odham, Cahuilla, Mojave, Piipaash, S. Paiute, Seri, Tarahumara, Tohono O'odham
Stick lac (Ethnobotanical)	15	Akimel O'odham, Cocopah, Mojave, Quechan, S. Paiute, Panamint, Seri, Tarahumara, Tohono O'odham
Lac applicator stick	8	Cocopah, N. Paiute, S. Paiute, Tohono O'odham, Tarahumara
Processed lac	16	Akimel O'odham, Apache, S. Paiute, Chemehuevi, Cocopah, Mojave, Quechan, N. Paiute, S. Paiute, S. Paiute/Chemehuevi, Panamint, Seri, Tohono O'odham
Knives	6	S. Paiute, Tohono O'odham
Tools, other	5	Akimel O'odham, S. Paiute/Chemehuevi, Seri
Food (*arí*)	1	Tarahumara
Total	**227**	

Table 14: Culture groups and number of artifact types found containing lac

Cultures	Number Objects	
Akimel O'odham	15	Arrow (3), awl, balls (6) gum/resin (2), mosaic, pottery (2)
Cahuilla	6	Mortar, pottery (3), rattle (2)
Chemehuevi	10	Arrow (4), gum/resin (2), rattle (4)
Cocopah	5	Gum/resin (2), rattle (3)
Hualapai	3	Rattle (3)
Kumeyaay	6	Rattle (6)
Luiseno	2	Rattle (2)
Mojave	20	Gum/resin (4), pottery (4), rattle (12)
Paiute, Northern	2	Gum/resin (1), fish spear (1)
Paiute, Southern/Chemehuevi	8	Arrow (2), awl (1), gum/resin (2) hooking stick (2), rattle (1)
Paiute, Southern	14	Awl (2), dice (2), gum/resin (5), knife (3), pottery (2)
Panamint	2	Awl (1), gum/resin (1)
Piipaash	4	Arrow (1), ball (1), pottery (1), rattle (1)
Pima Bajo	3	Rattle (3),
Quechan	3	Arrow (1), gum/resin (1), rattle (1)
Seri	61	Amulet (9), arrow (8), carving (21), gum/resin (7), harpoon (7), pottery (9)
Tarahumara	8	Arrow kit (1), gum/resin (3), pottery (3), rattle (1)
Tohono O'odham	49	Arrow (2), awl (7), container (1) gum/resin (6), knife (3), pottery (28), rattle (2)
Unknown	1	Pottery (1)
Yaqui	4	Arrow (2), rattle (2)
Replica	1	Mosaic (1)
Total	**227**	

by five artifact types: arrows, carvings, processed lac, pottery and rattles. Rattles were manufactured with lac by 14 groups, the most of any artifact type. Rattles made with lac were distributed between cultures found in all five regional groups, with more than half being from the Lower Colorado River region. Processed lac not yet manufactured into objects was found among 13 groups in the Upper and Lower Colorado River regions, the Sonoran Desert region, and in Sonora, Mexico. Carvings made with lac were found only among the Seri in Sonora, Mexico. Pottery with lac repairs or sealant was found among 8 groups, primarily in the Lower Colorado River region, the Sonoran Desert region and in the Sonoran and Chihuahuan regions in Mexico. Arrows made with lac were found in 7 groups distributed through all five geographic regions.

In the transition from the prehistoric to historic eras, some archaeological artifact types ceased in production, especially ornamental etched shell and mosaic objects with stone inlay (Table 11). The most common artifacts found made with lac from the archaeological period included arrows, knives, ornaments and pottery repairs. Knives found in the historic era were only rarely made with lac. Continuity is seen, however, in the production of arrows with lac in both the prehistoric and historic eras. Pottery repairs made of lac also persisted from the prehistoric to historic era in the Lower Colorado River region. Results of this study will be shared with institutions with lac containing objects in their collections to supplement, clarify, and in some cases correct their documentation. Future investigation will include examination of the collections viewed online but in person, requesting material characterization analysis where possible.

CHAPTER 5

Comcáac Ethnobiology:
Traditional Ecological Knowledge of Plants and Insects in Sonora to Hunt the Land and Sea

Introduction

The Comcáac (Seri) people of Sonora, Mexico have lived along the central Sea of Cortez or Gulf Coast and on at least two of its islands, persisting for millennia in the extreme desert environment thanks to their intimate traditional knowledge of the land and seascapes in the region. Water was always too scarce for farming, so instead they hunted and foraged the resources available on the land and in the sea, being mobile and flexible and always adapting to the conditions at hand for survival (Felger and Moser 1985, Nabhan 2003, Marlett 2014). As specialists of their landscape and seascapes, they have managed their natural resources, producing tangible material culture necessary for subsistence in such an extreme environment.

With intrusion of Spanish colonists and missionaries, and later Mexican nation builders between the sixteenth and nineteenth centuries, the Seri people had to adapt to a different sort of harsh environment: one laden with disease and warfare (Sheridan 1999). In the nineteenth century, the Americans first appeared in the form of anthropologists, while in the twentieth century American scientists, craft traders, and tourists arrived (Felger and Moser 1985). Again, the Comcáac people had to adapt to a new form of intruders. Comcáac history has been a narrative of adaptation to changing conditions combined with preservation of traditional language, custom, and knowledge.

This chapter will explore the unique history of the Comcáac, their relationship to their lands and sea, and the traditional ecological knowledge (TEK) and adaptive strategies employed to respond to rapidly changing conditions in the modern era. One may examine material culture as one manifestation of TEK to document continuity, as well as changes in Comcáac culture.

Exploration of some of the Comcáac's material culture, including their use of insect lac, illuminates some of those adaptive strategies for survival. The way that materials from the environment transform into objects of utility, ornament, ceremony, or the sacred with knowledge and skill can illuminate much about a people.

History in Deep Time

The Comcáac's origin stories tell of Giants who created the land and sea, the *xiica coosyatoj* "the ones who sing," of one who rubbed his thighs together, creating the Comcáac people as they fell to the ground (Herrera Marcos et al., 2015; Bowen 1976). The Comcáac led a highly mobile lifestyle over the centuries and did not leave as much tangible architectural evidence behind as their neighboring peoples on the Sonoran mainland. However, Bowen's extensive archaeological survey of Tiburón Island and the Sonoran coast indicates that people occupied the land as early as the Paleoindian era with the discovery of Clovis points for hunting of big game (Bowen 1976:89). A more recent study has found radiocarbon dated evidence of Clovis people in Sonora dating back to 11,500 BP (Sánchez 2016:132). Additional research indicates that the Comcáac are likely descended from the people of the Cochise Archaic culture of Sonora and south-central Arizona (Martínez-Tagüeña 2015). Evidence of later more established communities include utilitarian, ornamental, and probably ceremonial stone and worked shell objects. A very thin ceramic type called Tiburón plainware appeared, possibly dating between 150 AD and 800 AD (Bowen 1976:91; Bowen 2000). One scholar suggests the ceramic producing people of this era should be described as the Ancestral Comcáac Tradition (Martínez-Tagüeña 2015).

The Comcáac have lived in their landscape by the sea for millennia, and consequently have an intimate and deep knowledge of this ecosystem. The Comcáac perceive their history spatially more than chronologically in orientation, and this spatial construct, is an example of deep time history (Martínez-Tagüeña 2015). Martínez-Tagüeña explains that Comcáac express their understanding of deep time through oral history in three phases. The oldest phase is the time of the Giants, mentioned earlier. The most recent phase includes memories that date back to 1750. The middle phase is obscure due to memories lost from the later traumatic experience of violent conflict with the Spanish and Mexicans. Given that the Comcáac population was reportedly less than 200 by 1930, it is understandable that significant oral history would be lost (Kroeber 1931; Felger and Moser 1985). Through her research combining prior archaeological studies and contemporary collaborative ethnographic research with the Comcáac, Martínez-Tagüeña (2015) has been able to fill in some of gaps in that history. What is clear from this early historical research is the great length of continuity the Comcáac have with their landscape.

History in European and Mexican Colonial Time

The Spanish made their first expeditions into mainland Sonora in 1533 under the leadership of Diego de Guzman (Hrdlička 1904). Francisco de Ulloa circumnavigated the Sea of Cortez approximately six years later, sailing the channel between San Esteban Island and Tiburón Island, but never landed on either (Bowen 2000). In 1615, Iturbe, one of many who would sail the Gulf in search of pearls in decades to come, anchored off Tiburón Island, probably becoming the first European to meet the Comcáac (Bowen 2005:399). In the latter half of the seventeenth century the Europeans came and landed, among them missionaries, and with them

epidemic diseases also arrived, causing declines in Indigenous populations throughout the region (Bahre and Bourillón 2002).

Comcáac subsistence patterns before and during the colonial period relied on hunting with bow and arrows, gathering and storing wild plants with baskets and ceramic jars, and fishing with harpoons. Tiburón Island and the coastal areas supplied over 94 species of food plants, and a variety of edible mammals, and reptiles (Felger and Moser 1985, Nabhan 2003). The estuaries and sea provided shellfish, fish, sea turtles, sea lions, and sea birds to eat (Felger and Moser 1985:36). As Spanish settlements eventually encroached upon Comcáac territory, many Comcáac added Spanish domesticated animals to their diet through raiding, hunting slow moving cattle, but methods for acquiring sustenance otherwise changed little.

The first mention of the Comcáac in Spanish documentation was in 1645 by Pérez de Ribas, one of the missionaries to the Yaqui. He noted that Comcáac traded salt and deerskin with O'odham peoples for maize (Sheridan 1999:17). The first recorded contact between the Spaniards and the Comcáac happened in 1662 near Kino Bay, and the results were violent (Spicer 1962:105). In 1679, Father Juan Fernandez established a mission at Santa Maria del Pópulo for the Comcáac. The Comcáac abandoned it in 1683 after epidemics swept through. The Comcáac who lived there never settled permanently but migrated in and out of the mission and the desert. The Comcáac likely practiced this pattern long before Spanish contact, reflecting old trade paths with inland neighboring people (Sheridan 1999:17). It has also been estimated that only 10-20% of the Comcáac went to the two missions on the San Miguel River, Pópulo, and Nuestra Señora de Los Angeles (Sheridan 1999:97).

In 1685, Father Kino paid a visit to Tiburon Island and the Comcáac there welcomed him, but he left to establish missions farther north in Pimería Alta (Spicer 1962). Father Adamo

Gilg, who served the mission at Populo from 1688 and in 1692, wrote the first known ethnographic description of the Comcáac (DiPeso and Matson 1965). An example of his assessment of the Comcáac material culture is below:

> I will not waste much ink on their arts and craft; because there are few of them, and what they are, are as follows: they manufacture bows, quivers and arrows whose points heretofore were of stone; they weave mats of palm and reed; they bake pots and jars of unusual size; and finally, they tan the skins of wild beasts very nicely with the animals own brains and tallow. They knew nothing more than that before our arrival. It is no wonder that among them because ignorance ruled there, no order has been observed (DiPeso and Matson 1965:55).

Unlike other indigenous Sonoran people, most of the Comcáac were able to avoid the colonizing process of reduction by permanent relocation to missions. The Jesuits built missions miles inland from the coast in river valleys where there was reliable water and arable land. Attempts to move the Comcáac to these missions generally failed. After the Jesuit expulsion in 1767, the Franciscans tried to missionize the Comcáac and built the Carrizal mission near Kino Bay in 1772. It lasted only six months, when Comcáac men killed its priest, Father Gil (Spicer 1962; Sheridan 1999:405).

During the early years of contact and for centuries before, the Comcáac were not a single homogeneous group. Rather, they formed distinctive autonomous bands, at least six known historically, based on geographic location, and related subsistence activities. These bands, from south to north, were Guaymas, Upanguaymas, Tastioteños, Tiberones, Tepocas, and Salineros (Kroeber 1931; Mellado Moreno 2020). The significant impact of the Spanish colonial experience was the breakdown of this social organization with aggregation of the Seri bands into fewer groups, and a rearrangement of group territories (Sheridan 1999:12; Mellado Moreno 2020). In a sense then, the Spanish did succeed in reducing the Seri, but not as much as they had wanted, and not through the permanent settlement in missions, the adoption of an agrarian lifestyle, and the widespread conversion to Catholicism.

After the War of Mexican Independence in 1821, the approach towards the Comcáac continued much as before, with ever increasing warfare and conflict as ranchers moved farther west into Comcáac lands. The Mexican government also opened up Guaymas to international shipping and trade, bringing more outsiders into the region (Bowen 2000:91). As ranchers moved closer to the coast, the Comcáac would raid their livestock. The ranchers would retaliate, and the cycle of violence persisted for decades to come (Spicer 1962; Moser 1988). In the period between 1825 and 1832, the Spanish were preoccupied with the Yaqui revolt. With increasing Comcáac raids on ranchers, there were renewed expeditions to Tiburón Island in the 1840s to punish Comcáac living there, with hundreds of them removed from the island only to later escaped to the desert (Bowen 2000:231).

The nearly two-hundred-year era of resistance, conflict and warfare certainly took a toll when considering the severe population reduction of the Comcáac by late nineteenth and early twentieth centuries. Even with population declines, the Comcáac maintained some of their individual band identities, even amid the Mexican-Comcáac wars of extermination, by which time the total Comcáac population was less than 300. By the 1920s there were approximately 130 Comcáac remaining (Griffen 1959; Spicer 1962; Sheridan 1982; Felger and Moser 1985). According to Martínez-Tagüeña, some Comcáac still identified with different bands as late as the 1940s (2015).

The American Arrival

In the late nineteenth century, a new form of intruder came to Comcáac land, searching for objects of material culture to acquire to send back to American museums. Briefly in 1894 and again during a week in 1895, William McGee, a self-trained ethnographer, spent time surveying the Comcáac for the Bureau of American Ethnology and collecting artifacts for the National

Museum (Smithsonian). McGee judged the Comcáac to be "primitive" – "prolithic, not even Paleolithic", with "crude" mythology centered on the pelican. He described them as "treacherous and savage at war with thirst for alien blood like feral carnivores" (McGee 1898:97). McGee's racist assessment of the Comcáac influenced the attitude of Edward H. Davis, who had seven visits with the Comcáac between 1922 and 1939 on collecting trips for the Heye Foundation and the Museum of the American Indian in New York. Both anthropologists took photographs of the Comcáac and their environs, which are still very instructive. Alfred L. Kroeber, an anthropologist from the University of California, spent a week studying the Comcáac's society and language in 1930. He was openly critical of McGee's prejudiced and wrong evaluations, if not his observations (Kroeber 1931).

In the early 1940s, Gwyneth Harrington Xavier, an anthropologist who worked with the O'odham Indian Arts and Crafts Board, made trips to the Comcáac region. Her work regarding the Comcáac revealed a shift from the prejudice found in publications of many of her predecessors. She donated 300 Comcáac objects and associated field notes to the Arizona State Museum (ASM), enriching the collections' cultural and historic significance. Many of the anthropologists following Harrington from the 1950s, and the botanists and ecologists from the 1970s onward eventually donated their collections from the Comcáac to the ASM or other collections at the University of Arizona in Tucson. There are currently 1,807 "Seri objects" cataloged at the ASM, according to the curatorial database.

The twentieth century brought significant change to the Comcáac, the kind of change they resisted for hundreds of years under colonial rule and warfare with the Mexicans. The greatest change came in the form of economics and their induction into a cash-based market system of exchange for labor and goods. While non-Indian economic pursuits in the region

focused on extractive guano harvest for fertilizer, mining, fisheries, and agriculture, the Comcáac shifted from subsistence hunting, fishing and gathering to market based commercial fishing (Griffen 1959; Spicer 1962; Bowen 2000). As more people moved into the greater Southwest region on both sides of the United States border, demand increased for seafood. Kino Bay, once part of the Comcáac landscape, had become a major fishing community for the Mexicans by the 1920s. In 1930, a clubhouse was built there for sports fishermen and drinkers getting away from prohibition in the US (Griffen 1959; Spicer 1962; Bahre 2000). The totoaba fish became an immediate favorite due to its enormous size and profitability (Bahre 2000). The Mexican government established a cooperative for fisheries in 1938 to facilitate their new economy (Spicer 1962).

By the time anthropologist William Griffen and linguists Mary (Becky) and Ed Moser came to Comcáac land in the 1950s, the Comcáac had come to live primarily in two villages, Desemboque and Punta Chueca. The anthropologists and scientists were staying longer, for decades in the case of the Mosers, and the work became far more collaborative than in the past. The change in lifestyle accelerated and in part transforming for the Comcáac culture. The Comcáac no longer made their boats from reeds. Instead, they bought wooden boats from Mexican fishermen and used outboard motors and gasoline. In place of spearing fish and other sea life with homemade harpoons, they used gillnets and sometimes explosives. In place of their previous highly mobile lifestyle for collecting diverse foodstuffs from nature, they used cash to buy canned goods, flour and lard at *la tienda* in order to make fry bread. (Griffen 1959; Felger and Moser 1985; Moser and Marlett 2010).

The 1960s brought further changes and yet another form of outside intruders. Road construction gave access to the coast, in some areas with pavement, and with the roads came

American tourists (Bowen 2000:277). It was a long and slow drive to Desemboque from Tucson, but it could be done in a day (Yetman 2021). With the arrival of tourists, the Comcáac produced crafts for sale including shell jewelry and basketry, crafts long in use historically, and a new craft evolved specifically for tourists, carved ironwood figurines and sculptures (Nabhan 2003). The production of crafts for tourists further entrenched the Comcáac in a cash economy. In the 1970s, Kino Bay became a resort town, drawing in more tourists. The Comcáac migrated closer to Kino Bay in season for access to the tourist market and returned to Desemboque when the season ended. Infrastructure for electricity appeared in Seri communities in the same period (Felger and Moser 1985:14).

Additional changes to the management of the Comcáac landscape arrived in the 1960s. In 1963, the Mexican government declared Tiburón Island a wildlife refuge and conservation area, and in 1965, the government restricted the Comcáac from living on the island. In 1975, the Mexican government established the Comcáac *ejido,* communal property consisting of a 56 long kilometer strip (or 300 square miles) along the coastline. Ownership of Tiburón Island returned to the Comcáac, but their use of it remained restricted (Hine and Hills 2000; Salmon 2012). In 1978, Mexico declared all the Gulf Islands as areas of protection for flora and fauna. By this time, nearly all the sea turtles had become extinct (Felger and Moser1985; Bowen 2000). In 1995, all the Gulf Islands became designated Biosphere Reserves with stringent restrictions. Finally, in 2005 the Gulf Islands became a UNESCO World Heritage site with international recognition of their great biodiversity (Felger et al., 2013).

Despite these dramatic changes to the status of the landscape, Comcáac communities, and lifestyles, the enduring constant for the Comcáac has been their unique language. Comcáac language contains traditional knowledge, the oral history and the deep time memory of where the

Comcáac have come from and how they lived on their land along with its other inhabitants in nature. The language reveals Comcáac philosophy and knowledge of the environment from time immemorial. Even though the several individual bands have diminished over time, the Comcáac are still not completely homogeneous. Their knowledge persists with a specificity based on families and geographic ties to the land. Not all the people know all the same things about nature, for example, depending on where they came from originally (Martínez-Tagüeña 2015).

Comcáac Traditional Ecological Knowledge

Traditional ecological knowledge is defined in part as a "cumulative body of knowledge, practice and belief, evolving by adaptive processes and handed down through generations by cultural transmission, about the relationship of living beings (including humans) with one another and with their environment" (Berkes 2012:7). Comcáac oral histories and the early ethnologies prepared by outsiders illuminate Comcáac traditional subsistence practices, which include: the mobility to hunt prey, the ability to acquire the highly scarce resource of potable water, the ability to utilize a diverse resource base, and the ability to organize the people to obtain those resources (Nabhan 2000; Martínez-Tagüeña 2015; Felger et al., 2013).

Nabhan (2000, 2003) explains how many Comcáac plant names are associated with the animals that eat or depend on them. In many tribal areas the species and the associated language are disappearing. Among the Comcáac the language is extant but the ceremonial experience and "subsistence indicator" activities are disappearing with younger generations by 25% in 2000. (Nabhan 2000:1293) Nabhan calls this an extinction of experience regarding endangered species that breaks the connection between cultural and biological diversity that has operated for thousands of years. Interspecies relationship knowledge is disappearing faster than the native names. Nabhan suggests that the Federal and other land managers collaborate and communicate

with indigenous “parabiologists.” He argues:

> Scientists can foster such cross-cultural exchanges by asking open-ended questions and considering the ways in which each culture uniquely encodes its empirical knowledge and ethical values regarding wildlife. If the link between cultural and biological diversity is to be in any way maintained, strengthened, or restored, indigenous peoples must be included in the management and conservation of the world's remaining biological riches. (Nabhan 2000:1294)

Nabhan helped to establish a one-year certification program for “paraecologists” for Comcáac and biologists to learn TEK (Nabhan 2000).

Wilder et al. (2016) carried Nabhan’s ideas forward, arguing that indigenous citizen scientists in participatory research with professional scientists could most effectively catalog and document the biodiversity of the local ecosystem. This kind of collaboration is currently taking place with the Comcáac where they are taking leaderships roles and the Western scientists are taking the supporting roles in the research project. Traditional Comcáac environmental knowledge is utilized in multiple strategies, by combining ecological science with the sacred, and combining evolutionary biology with indigenous language and oral history (Felger et al., 2013). Wilder believes there is a crisis in time, that biodiversity is extremely threatened. He suggests more than ecological inventories are necessary. He proposes a wider approach that documents language terminology and taxonomy, plus the associated ecological knowledge. He suggests the congruence and incongruities between Indigenous and Western knowledge need documentation. To prevent such research from becoming terminal, indigenous language and intergenerational work must be strong components. Finally, indigenous local communities must be empowered and supported in choosing their own projects in managing their own land and seascapes. This broad approach will result in multicultural assessments of biodiversity and the necessary understanding to best manage the ecosystem and produce long-term resilience

strategies.

The Comcáac language continues to function as a key to the resilience of the people, their traditional ecological knowledge, and their land and seascapes. The language is an isolate, meaning it has no relationship to other languages. Some believe it belongs to the Hokan language family, but that is not definitive (Marlett 2008, O'Meara 2010). It is likely that the different bands of Comcáac had different dialects of the same language, all of which but one is now extinct. A majority of the approximately 900 -1000 Comcáac living today still speak the language in their daily life (O'Meara 2010; Moser and Marlett 2010). The language is also the foundation of the oral history and songs. Preserving one facilitates the preservation of the latter. Oral history can inform and improve what is known from scholarship of the past, whether from documentary history or from evidence-based archaeology. For example, Archaeologist Tom Bowen has used oral history to show that the historic Comcáac rode reed Balsas to travel to all the islands in the Sea of Cortez and that they also lived on San Esteban Island (Bowen 2000.) Another scholar, Salmon (2012) describes how contemporary Comcáac musicians are transferring traditional songs and language to youth filtered through the sounds of head banging heavy metal.

Comcáac culture and language in reference to lac scale insects, lac, and host plants

The Mosers, mentioned earlier, were linguists who lived with the Comcáac and transcribed much of their oral history into written text, eventually producing an extensive dictionary in Comcáac, Spanish and English. The following illustrates some of the language describing plant and insect lac exudates from the Comcáac-Spanish-English Dictionary (Moser and Marlett 2010):

- **iiqui cöcacaaiscan** cerrar bien. *close tight*. **Hamazaj quij ihapooin cop cöitapxazl, csipx quih iiqui cöimacaaiscan.** Tapó la olla y la cerró con resina. *He covered the pot and sealed it with resin.* (2010:84)

- **cacsipxa** *vc der* soldar, pegar con pegamento. *solder, glue*. **Ziix hacacj ihyaai hipcom he sacsipxa caha.** Voy a usar pegamento en esta figura de palo fierro que hice. *I am going to use glue on this ironwood figure that I made.* [*Conjug.:* **itacsipxa, itacsipxoj; itacsípxolca**] *De* **csipx** pegamento.

- **icacsipxa** *s obl abs* pegamento. *glue*. *Lit.,* con que uno pega.

- **ihacsipxa** *s obl pas —. V.:* **eenm ihacsipxa** soldadura, **ziix ziix iiqui cöihacsipxa** pegamento (2010:97).

- **hapoozi** *s suj pas —. V.:* **csipx hapoozi** un amuleto hecho de resina (2010:138).

- **csipx** *s* resina, especialmente resina de gobernadora que se usa como pegamento. *resin, especially creosotebush resin used as glue*. **Hesen hacacj zo htaai ma, ttápolquim ma, csipx pac toc cötoii ma, taax pac cohyacsipxa.** Cuando estaba haciendo una figura de palo fierro, se cuarteó, y la pegué con pegamento. *I was making an ironwood carving, but it broke, and so I glued it. V.:* **cacsipxa** soldar, pegar con pegamento.

- **Csipx csipx hapoozi** un amuleto hecho de resina. *an amulet made of resin*. *Lit.,* savia hecha en forma de pera. *De* **capoozi**.**csipx quiliti** un ciempiés grande con cabeza negra. *giant desert centipede*. [*Scolopendra heros*]. *Lit.,* el que tiene cabeza de "csipx". *Pl.:* **csipx quilitcoj**. *V.:* **coaazj**. **csipx quiliti (**2010:256).

- **hacaanoj** *s suj pas* resina derretida de "csipx".
melted "csipx" lac. [Se usaba para marcar las flechas, para identificación y decoración. *Used for marking arrows, both identification and decoration.*] *De* **cacaanoj**. *V.:* **hamác hacaanoj** señal de lumbre (2010:310).

- **ziix ziix iiqui cöihacsipxa** (**quih**) pegamento. *glue*. *Lit.,* cosa con que una cosa se pega. *De* **cacsipxa** (2010:633).

The Mosers not only preserved the language and translations, but also the traditional knowledge associated with the uses of the materials from environment and technology. Other entries in the dictionary include the names of plants and animals in the three languages. Examples of these are below:

- **cmapjöquij** *s.* 1) piojito (arbusto). *species of bush*. *Caesalpinia palmeri*. *Sinón.:* **hap**

oácajam. 2) sámota. *species of plant*. *Coursetia glandulosa*. *Sinón.:* **hehe ctoozi** (Moser & Marlett 1999:21).

- **haaxat** *s.* gobernadora, hediondilla. *creosote- bush*. *Larrea divaricata*. **Hitóaa cop halx xah xojízi taax haaxat iyat pac ihpáacloj ihpóoztoj ano hpsitóit haahi.** Me duele mucho el pie; voy a quebrar palitos de gobernadora y cocerlos, y luego voy a meter el pie en el líquido. *My foot hurts a lot; I am going to break some creosotebush branches and cook them and then I'm going to put my foot in the liquid. Pl.:* **haaxataj** (Moser & Marlett 1999:5).

Consider the complexity of knowledge in all the many terms used to describe the different features of a single useful pod producing desert tree, the mesquite: (Moser & Marlett 1999:7)

> mesquite pod **haas**. mesquite (young) **haas poot**. mesquite pod (dry, still on tree) **cöcootij**. mesquite pod (green, recently harvested) **haas coil**. mesquite pod (immature, soon after flowering) **haas ihazíinz**. mesquite pods (cooked) **haas hapáznij**. mesquite pods (cooked in hot sand) **haas hapásni**. mesquite driftwood **satómatox**. mesquite drink **haas hatíixp**. mesquite fiber after the mesquite has been chewed **haas hapáis**. mesquite rope **póosj**; **ipóosj**. mesquite thorn **xpeemoja**. ball of mesquite flour **haas hatócnij**. mesquite flour **haas copxöt**. immature mesquite pod **cocpémelx**. immature mesquite pod (after flowering) **ihazíinz**. immature mesquite pod (before flowering) **quisman**. rope made from mesquite **poosj**.

The knowledge of the lac insect expressed in the nomenclature and classifications in the Seri language shown above is an expression of the relationships between the people and the insects. The study of that local knowledge is the foundation of Ethnobiology, or more specifically in this case, Ethnozoology and Ethno-entomology (Hunn 2011).

Another kind of language or communication system containing traditional ecological knowledge is observable through the examination and interpretation of the material culture of a people. The way natural raw materials from the environment transform into objects of utility, ornament, ceremony, or the sacred with knowledge and skill can illuminate much about a people.

In some instances, examination of tangible material culture may also reveal aspects of intangible cultural significance, which can illuminate much about a culture's deep time memory as a compliment to oral history. For example, Salmon believes that Comcáac baskets represent resilience and the continuum and persistence of TEK. He notes, "Baskets create space for other more resilient parts of Seri culture to flourish" (Salmon 2012:126). The study of the plant and insect exudates in the material culture in the Southwest, including the Comcáac, also illuminates the cultural continuum.

That cultural continuum represented in material culture becomes increasingly important as TEK fades with succeeding generations, despite embedded knowledge in language, if aspects of that language are no longer used. According to interviews conducted by Cathy Moser-Marlett with Comcáac elders during time spent in Sonora during the fall of 2022, posing to them questions in a written questionnaire, she reported that in general the Comcáac people no longer knew much about *cspix* (lac) other than the elders she knew. The TEK about lac embedded in the language has been slipping away in recent decades. The elder informants reported they only knew of creosote bush as the source, that the plant produced the lac, and did not know about the insects. The only use of the material in recent times has been to fill ironwood carvings but even then commercial synthetics are more likely to be used today. The informants also noted that it was collected any time of the year, usually north of *Hatajc* (Pozo Coyote), which is north of Desemboque, and by anyone in the community. Branches of creosote bush with lac were cut off and taken home, the lac removed and kept in jars until needed (Marlett 2022).

Museum Collections Research and Results of Search for Lac in Comcáac Materials

The conservation laboratory at the Arizona State Museum (ASM) has analyzed the organic materials used as adhesives, coatings, and binders in the Archaeological Perishable collection, which consists of approximately 30,000 objects, as noted in Chapter 1. During the inventory process, conservators noted either absent or improper identification of adhesive materials in the catalog records, often in conjunction with incorrect object labels. Conservators were able to examine the objects containing resinous materials, analyze their composition, and as a result, clarify and in many cases correct the curatorial catalog records (Bisulca et. al. 2017).

As part of this research, studies extended into the Ethnographic collections, particularly the Comcáac artifacts. There are approximately 1,800 Comcáac artifacts at the ASM as of 2022. Material characterization analysis methodology included the use of ultraviolet (UV) light, chemical spot tests, and Fourier Transform Infrared Spectroscopy (FTIR). The objects were collected from the 1930s to the 1970s, mostly in Desemboque, but also in Punta Chueca, on Tiburon Island, in Kino Bay and in the generic Comcáac region, listed as Sonora.

Six additional Comcáac artifacts with lac from the Amerind Museum, dating from the 1940s and 1950s, were examined with UV light. An additional thirteen Comcáac artifacts from the online catalogs of the NMAI, NMNH and PMAE were observed. Of the sixty-one artifacts containing organic resins that were analyzed or examined along with documentation, fifty objects contain lac with certainty, four objects probably contain lac, and seven objects possibly contain lac, the latter two groups requiring further examination and analysis. The artifacts containing lac made by the Comcáac were identified as such by their collectors, and or donors, more than the material culture from any other group of people studied in this research. This may be partly explained by

the fact that all the objects were mostly collected after 1940, but it may also have to do with the Comcáac sharing the knowledge of the materials with the collectors.

Figure 46 Map of Comcáac (Seri) lands in coastal Sonora, Mexico, and the villages where lac containing artifacts have been collected.

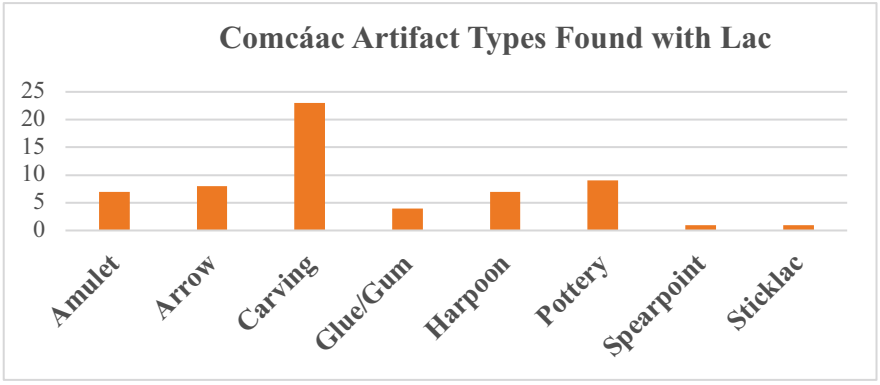

Figure 47 Chart of Comcáac artifact types found to contain lac in museum collections.

Use of lac for food procurement and storage

Before the Comcáac joined the cash-based market economy, the tools for subsistence were made by hand from local materials: soft woods, ironwood, carrizo cane, stone, shell, lac, animal and bird skin, turtle shell, and mesquite root cordage. Decorative paints were made of clays, minerals, and plant resin dyes (Felger and Moser 1985). The Comcáac used lac locally to manufacture arrows for hunting on land and for the harpoons and spears for hunting at sea. Lac was the adhesive employed to haft the arrowheads to the arrow foreshaft and then was wrapped with sinew (See Figure 48). Hunters carried lac in their kit as an available repair material (Felger and Moser 1985:141). On some arrows, the area below the sinew on the main shaft was decorated with paint made of heated lac. The lac would be melted with flame into a vessel of water through which horsehair would be drawn and then wrapped around the arrow creating black lines. This design would signify the arrow belonged to a Comcáac (Felger and Moser 1985:126, 128,141). The Comcáac also used lac as the adhesive to join points to harpoons and spears for turtle and fish at sea and on the shore. There were specific harpoons for turtle, fish, and crab. The lac for harpoon points came from either *Tachardiella larreae* or the *T. fulgens*, the two species most associated with cultural use by the Comcáac (Felger and Moser 1985:126-129). According to Marlett (2022) none of these tools and implements are still used and consequently lac is not used to manufacture them.

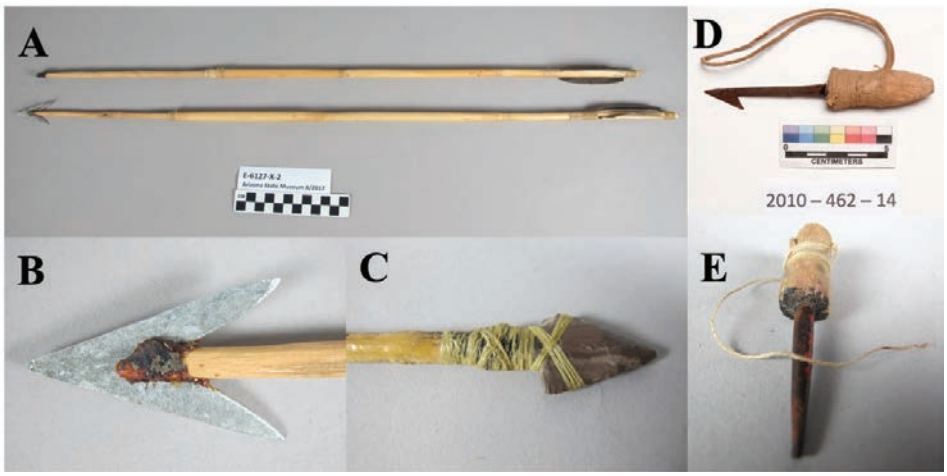

Figure 48 *Hacaanoj*: melted lac used for making arrows (Moser and Marlett 2010:310). Comcáac hunting and fishing tools made with lac. **A** Pair of Comcáac arrows, one with metal point, one without, collected in 1964 in Desemboque (ASM#E-6127-X-2) **B** Detail of metal point with lac hafting adhesive from (ASM#E-6127-X-2) **C** Stone point of Comcáac compound arrow, hafted with lac adhesive and bound with sinew (ASM#E-8628-X-1) **D** Harpoon point hafted with lac, collected by William Smith in Desemboque, c. 1950 (ASM#2010-463-14) **E** Toy harpoon point, hafted with lac, collected from Tiburon Island by Gwyneth Harrington in 1941 (ASM#E-1062).

The Comcáac used lac not only on tools to hunt and fish, but to hermetically seal in food stored in ceramic jars in cave caches. The heated lac was applied to the mouth of the filled jar and another ceramic or stone lid was stuck on, preventing pests from getting to the food and to keep it from spoiling. Among the foods stored in these jars were: agave, amaranth, saguaro, palo verde, goosefoot, wooly plantain, mesquite, organ pipe, and eelgrass (Felger and Moser 1985:91). An informant said in the past lac was applied to the rim of sealing jars for seeds with a hot knife but was no longer used that way (Marlett 2022).

Figure 49 *Hamazaj quij ihapooin cop cöitapxazl, csipx quih iiqui cöimacaaiscan***.** He covered the pot and sealed it with resin (Moser & Marlett 2010:84). **A** Seed storage jar contained seeds of the cardón (*Pachycereus pringlei*). Insect lac on rim and bottom of lid for sealing. (AFM# 6066A) **B** Rim of AFM#6066A jar under UV light, with lac fluorescing. **C** Comcáac storage jar with lid sealed on with lac resin, jar contained Eel Grass Seed (*Zostera marina*). Collected by Ed and Becky Moser in Desemboque, 1971(ASM#E-9940).

Cultural uses of lac, medicinal and spiritual

The Comcáac used creosote bush as a medicinal panacea like many people of the desert southwest. According to Felger and Moser (1985) the Comcáac were using it medicinally at least up to the 1980s as a poultice, smudge, tea for digestive and respiratory problems, and for stingray wounds. Lac was reportedly used as a contraceptive. It was prepared much the same was as lac paint, by melting it with fire into water, but in this case consumed (Felger and Moser 1985: 386).

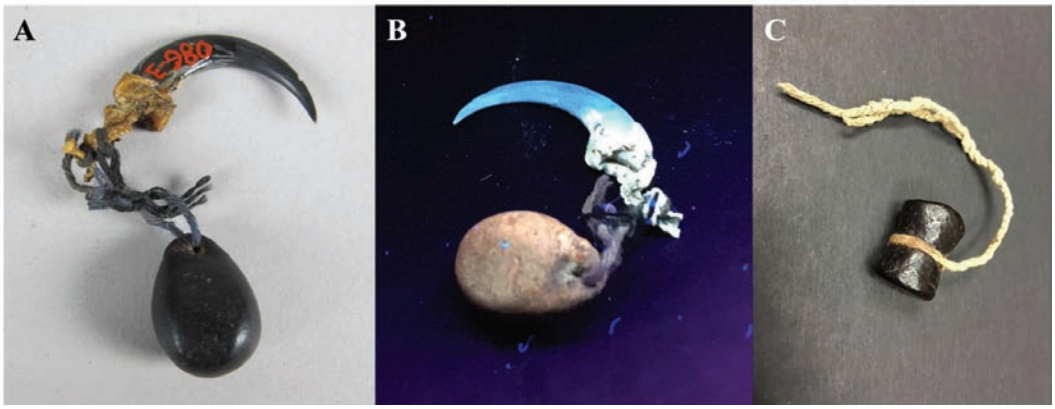

Figure 50 *Csipx hapoozi*: amulet made of lac (Moser and Marlett 2010: 256). Comcáac amulets collected by Gwyneth Harrington in 1941. **A** Amulet of lac secured to a osprey claw with cotton

string, collected at Tiburon Island (ASM#E-980) **B** ASM#E-980 under UV light, the keratin in the claw fluorescing blue and the lac amulet fluorescing orange **C** An hourglass shaped amulet tied with cotton cord, a common form for Comcáac amulets, collected at Desemboque (ASM#E-1936).

Lac also had less tangibly functional and more ceremonial or symbolic uses. Molded lac was used to make spiritual pendants or amulets to be worn on the neck, or hung in the home, sometimes in the shape of an hourglass. Several lac amulets from the ASM collections have an hourglass shape. According to Marlett (2014), some amulets were given to the youngest children of pregnant mothers who did not have milk to spare. These amulets often also included parts of birds or animals to impart extra strength. Gwyneth Harrington donated a lac amulet with hawk claw attached (See Figure 50 A, B) from one of her five expeditions to Comcáac lands between 1937 and 1944. In her field notes, Harrington (1941) described the amulet as a hawk's claw (*seh-po'h*) attached to a stone from a turtle stomach, which she called *kc-iip,* clearly a misspelling of *csipx*, which is lac, not a turtle gall stone. This was confirmed with FTIR analysis. The elderly Comcáac woman told her it was a "*cosa mirando*" a thing to look at, and that it was "*para illumbre*" or luminescent, giving light. When you look at the UV image of the object it does certainly become luminescent with fluorescence. It is something to ponder, for certain.

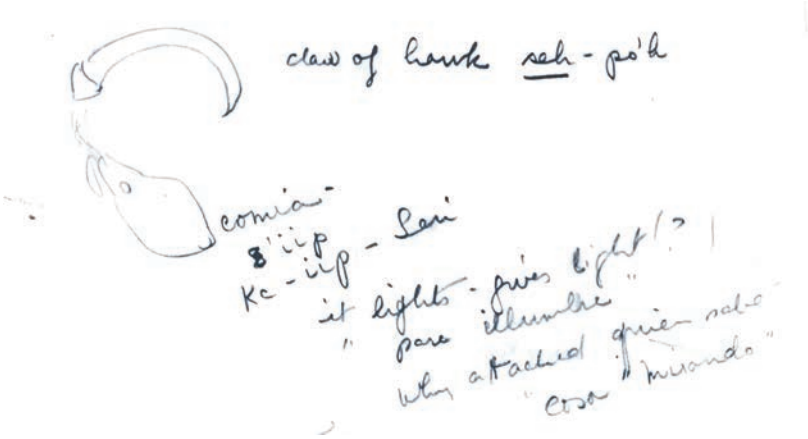

Fig 51 Illustration of amulet (Figure 50A) in Harrington's field notes (1941). Courtesy of the Arizona State Museum Archives.

Below her drawing of the clawed amulet (Figure 51), Harrington sketched the amulet with the hourglass shape (Figure 50C) and wrote, “lo mismo” meaning the same. A Comcáac informant told Harrington it was “a thing of the old people” referring perhaps to the Giants of the Deep Time, discussed earlier (Harrington 1941). Adults also wore amulets to ward off rattlesnakes when walking in the desert. Other possible Comcáac ceremonial uses for lac include paint for arrow decoration and, on occasion, to stuff the eye sockets of deer or rabbit headpieces for hunting decoys or dance masks (Felger and Moser 1985; Marlett 2014:41-42).

As with other previous uses of lac in Comcáac material culture, the knowledge of ceremonial and spiritual use has also disappeared according to elders who spoke with Marlett (2022). Today it is remembered as being a very strong glue, what they called “Seri glue” but not as having any value beyond its remembered utilitarian use. There was no knowledge of medicinal or ceremonial use, though there remains knowledge of the medicinal use of the leaves of the host plant, creosote bush (*Larrea tridentata)*. There were no songs or stories remembered of the material from the past (Marlett 2022).

Comcáac interaction with outside cultures through exchange

In Saitta’s (2000) discussion of Southwestern exchange, he contends that many of those who researched the topic in the late 1980s and 1990s had come to some consensus in believing that exchange is as much a social necessity as an economic interest. Exchange between groups facilitated alliances, assisted some groups in setting foodstuffs or other goods aside for leaner times, and in some cases perpetuated ideologies, as with objects with specialized iconographic designs. Saitta (2000) argues that exchange waxes and wanes over time and space in scale and complexity and that any scale society could be involved in exchange depending on their

circumstances, not only elites as others had suggested. During this period, archaeologists had come to a more macro perspective of exchange in the region, in fact, taking a regional approach and describing different groups in the Southwest as being systems.

Martínez-Tagüeña (2015) suggests that the Comcáac, who were highly mobile, interacted with and intermarried with their settled and agriculturally oriented O'odham neighbors. The O'odham wanted shell and the Comcáac may have wanted farmed produce, particularly when wild plant food sources were scarce. They probably set up an exchange network, which operated in ebbs and flows with alternating "pulses" of isolation, interaction, cooperation and competition (Martínez-Tagüeña 2015:18).

These "landscapes of interaction," people of different traditions coming together to obtain resources and things of symbolic value, could explain the movement of shell from the Seri region into other parts of the Southwest. While Marlett notes that there was extensive shell trade in the distant past, there is little evidence that the Comcáac traded shell any further than with their immediate neighboring tribes. Most of that trade took place historically in Hermosillo (Marlett 2014: 45-47).

After the 1960s when a Comcáac man, José Astorga began carving the dense and richly colored ironwood (*Olneya tesota*) figurines, a new craft trade was born. The Comcáac had been selling baskets, jewelry, dolls and the like at markets and to visitors, but the ironwood carvings became a highly desired product for art and craft dealers globally (Johnston 1968; Felger and Moser 1985; Yetman 1988; Sheridan 1996a:204-205). Yetman (1988:47) describes how he went on a lac (*csipx*) collecting trip with the carvers and watched how it was applied as a filler for imperfections and cracks in the wood, applied by dropping the resin on a hot knife and then pressing it in. Having looked at more than a dozen Comcáac ironwood carvings with lac fills

now, many are very hard to see without UV light to fluoresce the resin, as they are so well applied and blend in so well with the wood (See Figure 51). Johnston (1968) describes Comcáac ironwood carving in the early years, including several of the carvings, with illustrations, in the collections of the Arizona State Museum, where she worked.

Felger and Moser (1985:174) stated that in the 1970s, more than half the Comcáac adults were involved in what had become the carving industry. Today, with power tools available to cut down the ironwood trees, and with competition by mainland Mexican carvers, the industry has gone into decline, according to Mark Bahti, a Tucson dealer of American Indian Arts, and dealer of Comcáac carvings (Bahti 2022). As to the use of lac as a filler, Yetman (1988) noted that it was already being replaced by commercially made adhesives by the time he published his book, which is even more the case now according to Marlett (2022).

Figure 52 Examples of Comcáac ironwood carvings with lac resin fill **A** Frog figure, collected in Desemboque, Mexico, 1969. Details of lac fills under UV light below (ASM#E-9263) **B** Turtle figure, an early example of ironwood carving, collected by Ralph Michelsen c. 1960, Sonora with lac fill on verso under UV light below (ASM#2000-136-36).

Contemporary natural resource management by the Comcáac

The decline of ironwood as a natural resource, a necessity for the figure carving industry, and one that included the last known uses of lac, resulted due to an absence of natural resource management for the tree species. Despite that, there are several case studies from the last ten years that discuss the Comcáac approach to managing their resources where TEK is of great value in maintaining the sustainability of the resource base and their culture, which ultimately are interdependent. Basurto (2005) discusses the management of common pool resources (CPR) that are available to all, which can be depleted if over exploited. Fisheries are such a resource when unregulated. When there is open access to this kind of natural resource each member of the commons is motivated to maximize their own profit without regard for the sustainability of the resource that is exploited. Controls to access, such as restrictions for harvesting CPRS can prevent over exploitation. In this situation there is the potential for individuals to grant access to outsiders to a resource for a fee, which they keep for themselves, not the community and the outcome becomes a tragedy of the commons, where the individual benefits at the expense to the resource and the community. He uses the Comcáac fishery as a case study that has avoided the tragedy of the commons (Basurto 2005).

The Comcáac were granted exclusive fishing rights in their area as part of the *Ejido de Desemboque y su anexo Punta Chueca* agreement in 1975. The channel between the coast and Tiburon Island, the *Infiernillo*, allows for monitoring who has access to fishing far more than out on an open coastline. Geography in this case is one of the restrictions. The Comcáac practice the manual harvest of a certain shellfish at low tide in a centuries old sustainable practice. The entire community participates. It is an opportunity to monitor offshore commercial fisherman, poachers, as well as bring the community together to practice their TEK, sharing this knowledge

between generations. Basurto concludes that the Comcáac are "willing to grant access in exchange for economic gain up to the point where other value dimensions are not compromised. Self-interest has a contingent behavior" (2005:657).

From 2005 to 2009 the Comcáac collaborated with several public and private agencies to establish a program called "Ecoturismo Seri" in their area for sustainable economic development (Luque et al., 2012). In the 1990s Mexico, like so many nations at that time, deregulated its economy pursuing privatization and neo-liberal economic policies. In 1994 Mexico pursued a policy of Ecotourism linked to private developers to increase economically sustainable development projects. The Ecoturismo project was planned, marketed, and initiated by 2008 with three trained Comcáac families to introduce tourists to their landscape. Based on collaboration the Comcáac decided that sacred places on Tiburon Island would be protected from intrusion and ecotourists would only be allowed to visit the coastlines. The goal was to raise money by allowing visitors to come and tour the Comcáac estuary ecosystem with exposure to cultural experiences while minimizing the impact on the same environment. The program began well, but the economic crash of late 2008 combined with escalating problems with drug cartels in the region led to the program's unraveling. While there was some success with the project, a fundamental dilemma was revealed in its execution. The project had a strong profit motive as a not completely public program. The dilemma comes with its commodification of the culture and environment it is both selling and trying to protect. If such a project is revived, this dilemma will need to be addressed (Luque et al., 2012).

Wilder et al. (2016) describe a Comcáac case study based on a collaborative project between Indigenous leaders and Western scientists to utilize TEK to document biodiversity, particularly endangered species. Goals include improved resilience in the ecosystem and in the

use of Indigenous culture, TEK and language. This project was discussed earlier in detail. Monti (2003) considers Comcáac adaptive strategies using TEK to address modern problems with health. Martínez-Tagüeña (2015) looks at Comcáac TEK and sacred ecology. Given the extreme climate conditions of the area already, the issue of climate change, flexibility, and adaptability in remediation and response are more critical now than ever. As the case studies above indicate, planning and action are taking place.

Summary and Conclusions

This chapter has been an overview of the Comcáac and traditional ecological knowledge (TEK), which they have been able to nurture despite their turbulent history due to contact with outside intrusive cultures. As outsiders gained greater access to the Comcáac region in the twentieth century, the Comcáac employed adaptive strategies to respond to rapidly changing conditions in the modern era. The preservation of TEK is great part due to the Comcáac's unique still living language, which is finely attuned to the landscape they have known for thousands of years. The Comcáac were geographically isolated for many more years than many of their neighbors, which also contributed to their survival and their language's persistence even though they came so close to the brink of extinction from warfare.

Comcáac material culture also reflects adaptive strategies for survival. Material culture is another manifestation of TEK to examine to document continuity as well as change in Comcáac culture. The shift in types of material culture relates to the changes in their economics, from purely subsistent, to mixed subsistent, to completely cash-based market economics. Tools for hunting and fishing no longer contain lac, but lac use has recently continued for pottery repair. The knowledge of its use and where to find it persists today.

Having examined the use of lac in other cultures in the arid Southwest in Chapters 3 and 4, from the deep past of prehistory to more recent historical eras, it is possible to consider the Comcáac model to explore the TEK of these other regional groups of people who are known to have used lac. The exploration of TEK in a wider context could revive possible meanings, perhaps long separated or lost, since the belongings were collected, removed from their original context and curated into deep storage. A goal of this aspect of the research is to bring as much information about TEK found in repository collections to light.

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CHAPTER 6

Pigments in Scale Insects *Dactylopius* spp. and *Kerria lacca*: Historical Use, Biochemistry, and Function

Introduction

There are several pigment-producing scale insects and two have a long history of cultural uses through time, especially as textile dyes. One scale is from the New World, originating in the Oaxaca region of Mexico, later spreading through Latin America, the cochineal scale (*Dactylopius* spp.). The other originated in India, spreading through Asia, the lac scale (*Kerria lacca).* These insect-based dyes were highly valued commodities and trade items for hundreds if not thousands of years prior to the discovery of the synthetic chemical dyes that replaced them in the 19th century. Because of their high value, the pigments were the subject of much scientific inquiry in the past. Though no longer commercially employed as textile dyes, the use of insect pigments has been revived for food colorants and cosmetics, among other applications, as it has become apparent that synthetic dyes in food and cosmetics can be harmful to health.

Figure 53 Cochineal insects with dish of ground and processed cochineal. Sample of ground and processed lac dye pigment. Images courtesy of Imbarex and Kremer Pigmente catalogs.

Advances in analytical chemical and biological technology has since improved the understanding of the biochemistry of these insect pigments. The pigments of both scale insects consist of polyketide anthraquinone compounds (Brown 1975). The cochineal scale produces one polyketide-anthraquinone chemical, carminic acid (Wouters and Verhecken 1989). Lac scale produces several variations of laccaic acid consisting of seven different chemical polyketide-anthraquinone compounds (Pandhare et al., 1966; Rosenberg 2008). Both scales biosynthesize their respective pigments and do not acquire the chemicals from the phloem of their host plants (Rasmussen et al., 2018; Shamim et al., 2014). The functional roles of these pigment chemicals have been studied in the past but are still not completely defined or understood. Some studies have suggested the scale produce anthraquinones as chemical defenses against predators, but it is not certain those chemicals deter scale predators (Eisner 1980). It appears that some scale predator insects ingest the chemicals along with the scales and sequester them instead of being deterred.

This chapter will provide context and background of the history and geography of human use of carminic acid and laccaic acid produced by scale insects, as well as an overview of those insects and their ecology. This overview is adjacent to and useful for the study of the ecology and cultural use of lac scale in the desert Southwest. By examining the biochemistry and function of the pigments produced by the insects covered in the review, justification may be found to examine the related pigments produced by the four or more species of *Tachardiella* spp. found in the Sonoran Desert.

Literature on the biochemistry of the two pigment types is reviewed here, including description of the biosynthesis of the pigments, which was more recently explored and explained by entomologists and biochemists. Finally, there is discussion and analysis of the research

regarding the functional role of these pigments, what has been explored to date and what questions remain to be answered, to expand understanding of the biological role of the pigments in the scale insects. There has been a tendency by authors discussing pigment function to perpetuate the early research in the literature without further examination of the results.

Further examination of pigment function is necessary to be able to draw meaningful conclusions for both families of insects. At least six important questions about pigment function remain to be answered: Why are the pigment producing scale insects investing energy in producing a chemical if it is not very effective at deterring their own predators?. Why are they producing pigments when they are also producing soft coatings in the case of cochineal and hard lac resin in the case of lac scale? Can there be other functions of the pigment chemicals such as dual function chemical communicators as attractants to mutualistic ants in addition to the honeydew they produce, or as warning chemicals to some predators but not others? Could the pigments be a kind of aposematism, a warning color but with little chemical defense? And, finally, could the purpose be more microscopic in defense against bacteria and viruses? These are questions that persist regarding the various laccaic acid pigments in the *Tachardiella.* lac scales in the Southwest. Given the continued economic importance of the pigments acquired from cochineal and Asian lac scale, research on those pigments could help provide some related answers as to the actual biological functions.

Dactylopius spp. *and Kerria lacca:* Overview of the insects and historical use of their pigments

Dactylopius spp. is in the Dactylopiidae family, in the Coccoidea superfamily, in the suborder Sternorrhyncha and in the order Hemiptera (Ben-Dov 2006). Of the nine species of

Dactylopius that live in the wild, the species that was most often used to produce cochineal dye has been *D. coccus,* which relies on the host plant *Opuntia ficus-indica* for its productivity (Chávez-Moreno et al., 2009; Chávez-Moreno et al., 2011). Phylogenetic research indicates that *Dactylopius coccus* arose in the current area of Oaxaca, Mexico (Van Dam et al., 2015). Evidence of cochineal dyed textiles found in Mexico date back to the 4th century BCE and cochineal propagation on *Opuntia* spp. is documented in Aztec codices dated to 1511 (Donkin 1977b). In Peru, evidence of use of cochineal for textile dye dates to the 3rd century BCE (Cardon 2007). Not long after the Spanish arrived in Mexico in the 1500s, dried unprocessed cochineal was shipped in bulk to Europe from where it was traded around the world over the next three hundred years (Baranyovits 1978). Eventually, due to high demand and Spanish influence, production of cochineal spread from Mexico into Central American countries, the Caribbean and Post-Colonial South America (Donkin 1977b). *Dactylopius* spp. is currently distributed around thirty-three countries in the world either as a native or introduced species (Chávez-Moreno 2011).

Kerria lacca is in the *Kerriidae* family, in the *Coccoidea* superfamily, in the suborder Sternorrhyncha and in the order Hemiptera (Ben-Dov 2006). The use of insect lac from this species for medicinal and other purposes was documented in ancient Indian texts dating to 1500 BCE and use of its pigments as a dye for silk has been documented in Han Dynasty China in approximately 200 BCE (Donkin 1977a; Cardon 2007). Lac chemical components and resin have been used historically as dyes, pigments, adhesives, coatings, varnishes, and inks, as a stiffener for hats, in the shoe and leather industry, and as the primary component of record albums before the use of vinyl (Colton,1943b; Ghorai 1995; Maiti and Rahman 1986). More recently lac has been used in cosmetics; in the food industry as a coating for fruits, vegetables,

and confectionaries; in dentistry for denture production; as an electrical insulator and as a coating in the pharmaceutical industry.

A more recent study of the ecology of the lac insect in India describes the abiotic and biotic factors involved in the successful production of lac. The primary host plants for *Kerria lacca* in India are the *Butea monosperma* (Palash), *Zizyphus mauretania* (Ber), *Schleicheria oleosa* (Kusum) plus several varieties of *Acacia* and *Ficus* trees (Ghorai 1995). There are many interesting trophic and ecological dynamics in the lac production system, including facultative mutualism with ants (Bhattacharya et al., 2016). The distribution of lac production spread from India to China, Tibet, Sri Lanka, Nepal, Myanmar, Cambodia, and Vietnam (Donkin 1977b). Industrial lac production is still prominent in India and in Thailand (Ghorai 1995).

Both cochineal dye and lac dye produce brilliant scarlet colors, especially when combined with aluminum or tin mordants, which made them highly desirable. Both dyes adhered best to proteinaceous fibers such as wool and silk and are resistant to fading from light or water. Lac was also a popular dye for leather (Donkin 1977b; Wouters and Verhecken 1989). Before synthetic dyes were produced in the 19th century, the dyes produced from scale insects were among the most important commodities for the textile industry in the world (Brown 1975). After synthetic dyes were produced for the textile industry, cochineal and lac-based dyes declined drastically due to cost efficiency. The first synthetic dye was developed in England in 1856. Alizarin was synthetically produced in 1869 with a formula very similar to the scale insect pigments ($C_{14}H_8O_4$). Over time cochineal commercial use shifted to dyes in foods, pharmaceuticals, and cosmetics, replacing the use of Red Dye No. 2, which had adverse health effects (Dapson 2007; Cooksey 2019). Lac dye has generally become commercially obsolete and

is washed away as a waste product in the continuing lac resin (shellac) and wax production industries for varnishes and other commodities (Thomson 1971; Cardon 2007).

Biochemistry of *Dactylopius* spp. and *Kerria lacca* - structural and physical properties

It is safe to assume the Indigenous peoples of Latin America who were propagating cochineal scale for production of dyes and paints knew that the organisms containing the pigment were insects. The Colonists who had acquired the material to send back to Europe for the textile industry and trade did not understand the nature of the material until 1866, when a French naturalist determined the scale was an insect and not a plant (Baranyovits 1978).

The two scale insects, cochineal and lac, are similar in life cycles. The females are sessile once they latch onto their host plant for feeding and breeding while the males have wings and can make short distance flight or be dispersed by wind during their brief lives (Colton 1943b; Baranyovits 1978). The hatchlings of both scales emerge red, already containing their respective anthraquinone compounds. Both scales produce a protective coating. The cochineal scale exudes a soft white waxy coating that is as much for protection from heat and desiccation as for protection from predation (Baranyovits 1978; Cruz 2019). The lac scale exudes a hard wax-polyester oligomer resin coating that offers protection from predation (Bisulca et al., 2017). The lac coating probably provides protection from heat and desiccation as well, particularly in more arid environments.

In their paper on defensive chemicals secreted by arthropods, Eisner and Meinwald (1966) note that early analyses on insect exudates were conducted in the 17th century. The French chemists Pelletier and Caventou were the first to study the chemistry of the pigments in cochineal (Cooksey 2019). It is notable that these two French scientists also discovered caffeine.

It was not until the early twentieth century (1909-1920) that German chemists, Otto Dimroth and associates, identified the primary chemical component of the cochineal pigment as carminic acid and classified it as an anthraquinone compound, establishing the anthone-anthraquinone relationship. Dimroth also examined and identified the laccaic acid in lac scale pigment in 1913. Other chemists revised Dimroth's work in the 1960s and later (Pandare et al., 1966; Thomson, 1971; Lloyd, 1980). For example, Pandhare et al. (1966) revised the chemical formula for laccaic acid A to $C_{26}H_{19}N0_{12.}$ Thomson (1971) later determined that all the pigments found in insects are polyketide anthraquinones and that they differ chemically from the anthraquinone compounds found in plants. Additionally, Thomson (1991) also noted that there are hundreds of different quinones found in plants, fungi, bacteria, and marine organisms, and there are forty-eight different quinones in insects.

In 1975, Brown concurred that polyketide anthraquinones were foundational to the insect pigments. Wouters and Verhecken (1989) analyzed cochineal and lac dyed wool fiber using High Performance Liquid Chromatography (HPLC) and found that cochineal consists of 94-98% carminic acid. The major lac dye component is laccaic acid A (71–96%). Most of the remainder (0– 20%) is laccaic acid B (Rosenberg 2008). The minor component, laccaic acid D, is identical to flavokermesic acid, which is a chemical link to the other insect dyes (Wouters and Verhecken 1987). Again, because the cochineal and lac scale pigments were of economic importance, their chemical analysis was deemed valuable for developing industrial scale production in the past. Today there is also interest in identifying dye sources in prehistoric and historic fabrics, shedding light on trade routes and dye knowledge. Analytical tools such as high-performance liquid chromatography (HPLC), gas chromatography-mass spectrometry (GC-MS) and Fourier-transform infrared spectroscopy (FTIR) have become more affordable, and therefore more

accessible to a wide range of interested researchers (Cooksey 2019; Lech et al., 2015; Santos et al., 2015; Vashishtha et al., 2013; Rosenberg 2008). Likewise, there is renewed interest in use of insect pigment sourced colorants in foods and other products (Wu et al., 2017).

Chemical structures, formulas and descriptions of carminic acid and laccaic acid A (the primary component of lac insect pigment) as they are known today can be found below in Figure 54, plus some description of the anthraquinone class of chemicals for background.

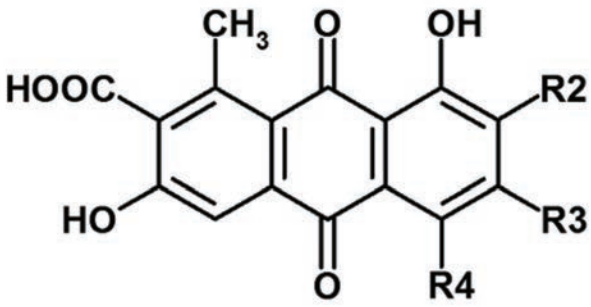

Figure 2. The chemical structures of the cochineal red dyes.

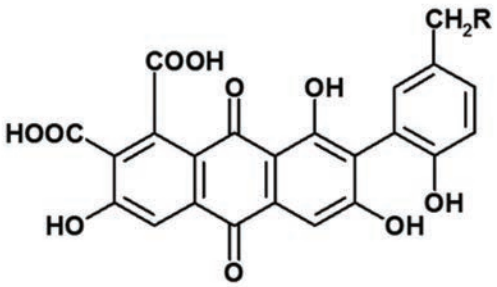

Figure 3. The chemical structures of the red lac dyes.

Figure 54 Carminic Acid structure
Source: (Cooksey 2019)

Carminic acid ($C_{22}H_{20}O_{13}$)
glucosidal hydroxyanthrapurin

Laccaic Acid A structure
Sources:(Cooksey 2019; Shamim et al., 2017)

Laccaic Acid A ($C_{26}H_{19}O_{12}$)
3,5,6,8-tetrahydroxy-9,10-anthraquinone

The chemical compounds for the other variations of Laccaic Acid are as follows:

Laccaic Acid B: ($C_{24}H_{16}O_{12}$)
Laccaic Acid C: ($C_{25}H_{17}NO_{13}$)
Laccaic Acid D: ($C_{48}H_{27}AIO_{21}$)
Laccaic Acid E: ($C_{24}H_{17}$ NO_{11})
Laccaic Acid F: ($C_{26}H_{18}O_{13}$)
Laccaic Acid Rangbatti: ($C_{20}H_{14}O_{10}$)
Source: PubChem 2019

Anthraquinones are chemicals in a large class of naturally occurring phenolic compounds, belonging to a family of polycyclic aromatic hydrocarbons, formed from an anthracene ring (tricyclic aromatic) with a keto group on carbon atoms nine and ten (Shamim et al., 2014). Anthraquinones are produced when oxidized with potassium dichromate/sulphuric acid of polycyclic aromatic hydrocarbons (Shamim et al., 2014). The precursor chemical to

carminic and laccaic acids, the anthracenes, are solid polycyclic aromatic hydrocarbons of three fused benzene rings seen at the center of both chemical structures above. Anthracene was the foundation chemical to produce the synthetic dye alizarin and others that eventually supplanted the natural dyes made from the insect pigments (Cooksey, 2019).

Biosynthesis: the origins of carminic and laccaic acids in scale insects

Early in their study of chemical ecology and insects, Eisner and Meinwald (1966) stated that despite scant research at the time, they believed that the arthropods were synthesizing the pigments themselves from their own metabolic precursors. Brown (1975) later speculated that the insect pigments could be synthesized by endosymbionts, but he believed more strongly the pigments were produced by aphids and scales themselves via biosynthesis. He concluded that none of the pigment compounds had any relationship to the host plants on which the insects lived but felt the method of pigment production was still open for debate. Brown (1975) also found it notable that anthraquinone pigments and polyketide naphthotriols, among a few other compounds, were common products of biosynthetic pathways and were rarely known outside of aphids and scales among the insects. Later, Eisner et al. (1980) noted that newly born cochineal scale and the males were red from carminic acid. The same is true of the lac scale insects. The chemicals are also present in the blood and muscles of the immature and adult insects and in eggs and embryos of gravid females. Eisner et al. (1980) used HPLC and bioassays of ants fed carminic acid to quantify these observations.

Thomson (1991) indicated that the coccid pigments are still generally considered to be polyketides but that their precise origins are still unknown, suggesting they may be produced by endosymbionts. Research by Bustamante-Brito et al. (2014) did verify the presence of *Wolbachia*

strains in *D. coccus* which they named *Dactylopiibacterium.* These bacteria were found primarily in the hemolymph and less so in the gut. These bacteria were not found to have anything to do with carminic acid production but were instead involved in provisioning the scale with necessary nutrients and amino acids (Bustamante-Brito et al., 2014). Kannangara et al. (2017) isolated another C-glucosyltransferase from *D. coccus* thinking it may have contributed to the formation of carminic acid. Their research also concluded, however, that the pigment was biosynthesized by the cochineal scale itself.

The symbionts of the Coccoidea, including the aphid superfamily (Aphidoidea) are host-restricted, and the microbes are more likely to adapt to their hosts evolving with their insect host lineage over time in a co-diversification process. Coccoidea is a sister group of Aphidoidea (Moran, 2001). Co-diversification is indicated by matching phylogenies revealed through genetic analysis (Moran et al., 2019). According to Moran (2001) *Buchnera aphidicola* lives in the bacteriocytes in the mother aphid and transmits vertically to the offspring in the egg or embryonic stages. Vertical transmission takes place when the mother passes microbes directly to her offspring, between the different generations. Horizontal transmission takes place when one individual passes its microbes to another individual of the same generation through direct contact or indirect contact. In horizontal transmission symbionts can also pass from the environment to the host (Kucuk, 2020).

The *Buchnera* are nutritional microbes that provision the aphid with amino acids, which are lacking in the phloem on which they feed. Research on some species of aphids and the *Buchnera* gut microbes indicate an endosymbiotic relationship dating over 100 million years (Moran, 2001). The antiquity of the relationship between aphids and *Buchnera* implies that other

phloem feeders in the Sternorrhyncha suborder likely had infections and common ancestors with ancient endosymbionts as well (Moran 2001).

This pattern of ancient endosymbionts likely also applies to the microbes that provision the nutrition of the *Kerria* lac scales (Vashishtha et al., 2011). *Wolbachia* bacteria and a fungi, or what they called a yeast like symbiont (YLS), have been found in association with the lac. Vashishtha et al. (2011) suggested the YLS of subphylum *Pezizomycotina* is maternally transmitted and probably obligate, is found in the intracellular adipose cells of the fat body and provisions the insect with nutritional benefit. They contend that the *Wolbachia* may manipulate the male female sex ratio of the insect. Shamim et al. (2017) identified an additional eight species of bacteria associated with *Kerria lacca* that are possible endosymbionts but did not yet know their function. Shamim et al. (2019) studied the bacterial communities found in *Kerria lacca* honeydew and suggested that many of the twenty isolates could have been endosymbionts that were excreted out of the insects. Ants feed on the honeydew produced by lac scales, acquiring sugars as nutrients and in turn prevent fungal invasion of the scale anus, benefitting the scale's fitness. The ant also guards the scales from predators, providing additional benefit to the scale. The research on honeydew bacteria appears to be ongoing.

Host restricted gut microbes are called obligate, indicating a dependent relationship. Both the host and the symbiont co-specialize over time. In this relationship the host insects depend on the gut microbe for survival, meaning they cannot live without them. Facultative microbes are non-host restrictive, indicating a more independent relationship. *Wolbachia*, again, one of the microbes found in *Kerria lacca*, is an example of a facultative endosymbiont (Engel and Moran, 2013). Obligate symbionts are transmitted by vertical transmission while facultative symbionts can be transmitted both vertically and horizontally, the latter between the environment and the

host insect (Kucuk, 2020). Moran et al. (2019) conclude that the primary functions of gut microbes are to extract nutrition from the environment, to prevent invasion by pathogenic organisms and to provide new capabilities to their hosts. They aid in digestion, in biosynthesizing nutrients, in detoxification and in excluding invasive pathogens to the host.

Moran et al. (2019) describe this persistent association between gut microbes and host insects as a type of addition, or evolved dependence, without which the insect could not survive even if neutral or detrimental in impact. If the relationship is beneficial then the gut microbes are even capable of expanding the ecological niche or range of the insect, enabling the use of new foods. Perhaps this phenomenon could help explain how typically tropical living scale insects could adapt to arid land environments and plants over time, like *Tachardiella* spp. found in the Mojave, Sonoran and Chihuahuan deserts.

It was not until 2018 that research on the biosynthetic origins of carminic acid found evidence to support the hypothesis that all pigment producing coccid insects shared a common flavokermesic acid (FA) core, and that suggests they all share a similar biosynthetic pathway in the production of their pigments. Rasmussen et al. (2018) found structural similarities and co-occurrence between many families in the coccid superfamily, suggesting long and close evolutionary origins. The likely biosynthetic pathway for pigment production in the scale insects is the polyketide synthase (PKS) pathway. The polyketides in insects likely evolved from type I fatty acid synthases (FAS) with which there are many similarities (Rasmussen et al., 2018; Shamim et al., 2014). In another study of the possible biosynthetic pathways for *Kerria lacca* Shamim et al. (2016) sequenced thirteen related genes from lac insects from India. Their results concur with Rasmussen et al. (2018) in that they found that the lac insects also biosynthesized their pigments through a polyketide synthase pathway (PKS). They found that a complex type II

polyketide synthase was the enzyme precursor for production of laccaic acid D, which is the common lac pigment precursor (Shamim et al., 2016). It is important to note that laccaic acid D primarily consists of flavokermesic acid, the same core precursor chemical of the coccid insects found by Rasmussen et al. (2018).

While researchers are closing in on a definitive explanation of the biosynthesis of pigments by the scale insects, further research and genetic mapping is required to make final conclusions. What has been made clear from this research is the similarity between the origins of the pigments in the different species in the coccid superfamily. Perhaps the biological functions of those pigments will also share similarities, something not yet adequately studied.

The role of carminic and laccaic acids in chemical defense of the scale insects

According to Baranyovits (1978) there was still no adequate explanation of the biological role of carminic acid in the cochineal scale, what the author described as a "seemingly useless chemical." There was also no understanding at the time of how carminic acid was produced. Eisner et al. (1980) were the first to attempt to describe the biological function of carminic acid. The authors reported it was known that some insects like millipedes produced quinone chemicals as effective anti-feedants in defense of predators like ants. Eisner et al. (1980) analyzed the carminic acid from the cochineal scale (*Dactylopius* spp.) to determine whether it had a similar deterrent effect. They ran tests on the cochineal scale species *Dactylopius confusus* growing on prickly pear cactus (*Opuntia* spp.) found that one species of moth larvae feeding on the cochineal scale was not negatively impacted and instead sequestered the anthraquinone for its own use as a deterrent from feeding by predatory ants. The moth larvae regurgitate the consumed anthraquinone of the cochineal on the offending ants causing them to desist attack. Based on

these experiments, Eisner et al. (1980) surmised that carminic acid evolved in the (*Dactylopius* spp.) as a chemical defense, and that the recently hatched and male scales who were not covered in the white waxy protective coating were those most benefitting from the chemical, with the red color acting as a visual warning to likely predators. The authors also suggested the red colorant in other pigment producing insects, lac and kermes scales, would have a similar function. It is important to note that the authors did not claim the role of carminic acid in cochineal scale functioned as a chemical toxin or irritant but suggest it functioned as a chemical deterrent.

Continuing the research into carminic acid sequestration by cochineal scale predators, Eisner et al. (1994) examined the larvae of two other insects, a coccinellid beetle [the Trident Lady Beetle (*Hyperaspis trifurcata*)] and a chamaemyiid fly [the Aphid Fly (*Leucopis* sp.)] While the scale-feeding snout moth, mentioned above, regurgitated the sequestered carminic acid on ants, the trident lady beetle defecates the carminic acid, and the aphid fly exudes the acid as hemolymph when provoked by predators, in most cases ants.

Pankewitz et al. (2007) reported that anthraquinones have a defensive function based on Eisner's and Avery's earlier research. Likewise, Dapson (2007) reported that carminic acid is still assumed to function as a predation defense but noted that it has not been an especially good defense, since cochineal scale predators nearly wiped them out more than once in both Mexico and Peru historically. In reviewing historic literature on the roles of both carminic and laccaic acid, it became clear that the idea these insect pigments performed as chemical defense in the scale insects was perpetuated from studies of Eisner et al. (1980; 1994). Numerous authors referenced Eisner et al.'s work and included mention of carminic acid as a defense chemical, thereby perpetuating the concept without including the proper discussion of details in most cases (Thomson 1991; Garcia- Gil 2010; Ramirez-Puebla 2010; Dettner 2015; Shamim et al., 2016;

Kannangara et al., 2017; Rasmussen 2018; Bustamante-Brito et al., 2019). For example, Ramirez-Puebla (2010) stated that carminic acid is used by insects for protection against predators. Bustamante-Brito et al. (2019) qualified but also stated that carminic acid in the insect may function as a defense against predators. Kannangara et al. (2017) was the most cautious of these researchers, describing carminic acid as a deterrent to ants, not a defense. None of these papers experimentally examined the role of carminic acid in lab or field trials, but deferred to the conclusions of Eisner et al. instead, given that they are considered the leading experts on insect chemical ecology. However, perceptions may be shifting now. For example, Austin Cruz, a PhD student at the University of Arizona who studied the ecology of cochineal scale and its host plants, concurred that in his observations carminic acid is not a very effective chemical agent against predation (Cruz 2019).

Though experimental research on the biological function of carminic acid and laccaic acid has not been further pursued since Eisner et al. (1980, 1994), additional research has been conducted on the anti-feedant properties of the anthraquinones that are also found in carminic and laccaic acids (9,10-anthraquinone) towards birds. Hilker and Köpf (1994) discussed the effective treatment of fruit orchards with anthraquinone based compounds and Avery et al. (1997) described the efficacy of anthraquinones as a direct repellent on rice seed. Shamim et al. (2016) examined whether the laccaic acid found in Indian lac exhibited the same anti-feedant properties as the carminic acid in cochineal, based on the work by Eisner et al. (1980, 1994). In India, many of the lac species used in commercial production are tended by ants against predators in a mutualist relationship. Their results showed that some types of lac had a stronger deterrent effect on ants that others, those with higher laccaic acid D (higher in kermesic acid) were most susceptible to the ants tested. The authors concluded there was still a gap in the

understanding of the antifeedant function of the lac pigments and that it required further research (Shamim et al., 2016).

There is another line of research related to the source compounds found in the scale insect producing pigments that deal with the antimicrobial properties of the anthraquinones and other characteristics of the insects themselves. This research is medical and pharmaceutical in nature but may, in the end, help explain another aspect of the biological function of the pigments for the insects that produce them. Cudlin et al. (1976) found that hydroxyanthraquinones and their glycosides had antibacterial effects on several different bacteria. Unfortunately, the results were negative for E. coli, which was included among the species tested. Barnard et al. (1992) found that anthraquinones and derivatives had positive anti-viral effects on human cytomegalovirus (HCMV) which causes serious infections in patients with immunosuppressed conditions. One of the anthraquinones with positive effect was alizarin, the synthetic compound produced to replace the natural carminic and laccaic dyes.

In a study directly involving the carminic acid produced by *D. coccus*, García-Gil De Muñoz et al. (2007) found that free oxygen radicals were generated from the cochineal scale hemolymph, where a majority of the carminic acid it synthesized is found. This research also showed that carminic acid could be used to generate reactive oxygen intermediates (ROI) and reactive nitrogen intermediates (RNI) which have anti-microbial properties. In this study the authors found the carminic acid had anti-bacterial effects on the bacteria *M. luteus*, which can cause skin infections and in extreme cases septic shock. The authors suggest that for the *D. coccus* the bacteria may prompt the ROI generation and contribute to bolstering immunity in the scale from bacteria, thereby defending the scale on an internal and microbial level. In another study where the carminic acid pigment from cochineal scale and laccaic acid pigment from lac

scale were fed to lab rats with thyroid cancer, the results showed that the laccaic acid had an inhibitory effect on tumor development. However, the carminic acid had no effect on the tumors (Kemmochi et al., 2010). Another recent study investigating the use of laccaic acid as a treatment for cancer found the laccaic acid had potent antitumor effects on colorectal cancers through dual inhibition of DNA methyltransferase-1 and histone deacetylase-1. The laccaic acid had the added benefit of being non-toxic compared to many other chemotherapies for cancers (Gupta et al., 2019).

Conclusions and future research

This review of research has illustrated the continued interest in and exploration of the pigment producing insects, particularly the cochineal scale *(Dactylopius* spp.) and lac scale (*Kerria lacca*). Due to the high economic value of these pigments from antiquity to the Industrial Revolution with the advent of synthetic dyes, there was high interest in determining the biochemistry of these desirable compounds. As interest has revived in the use of the pigments for food and cosmetic colorants, anti-bacterial preservatives for food and cosmetics, and more recently as sources or components with pharmacological applications, scientific inquiry has continued in determining the insects' genetics and methods for their pigment biosynthesis. All this continuous research has explained much about the pigment producing coccid scales.

What remains unclear is the complete explanation of the biological function of the production of pigments for the scale insects. The work of Eisner explained that the carminic acid probably evolved as a defense for immature scale insects and emergent males not yet covered by cochineal wax or lac resin. Eisner also showed that in the case of cochineal, the carminic acid may be a deterrent to predacious ants while they produced sugar to attract the defending

mutualist ants. Eisner's work and other scholars' observations also showed, however, that the carminic acid does not function as an actual chemical defense of the scale, since so many predatory insects feed on them despite the red colorant. Both the cochineal and lac scale expend additional resources producing their wax and resin coatings, respectively, in part to protect from extremes in temperature and relative humidity, but also for protection from predators. No further studies on biological function of the pigments have been pursued since Eisner, outside of the studies on the anti-avian effects of the compounds on seeds.

There is ongoing interest in these pigments in a variety of fields outside of entomology. Historians and art conservators have renewed interest in analyzing textiles and other objects where the pigments were employed as dyes and colorants for proper identification, dating and for gathering data to inform best practices in long term preservation. The cosmetic industry is interested in continued use of the pigments as colorants. The food industry is interested in applications of the pigments for colorants, and perhaps more importantly as antimicrobial preservatives. The medical industry and pharmacological industries are most recently interested in the antibacterial, antiviral and antitumor effects of these pigments.

It is the implications from the medical research that may ultimately complete the explanation of the biological function of the pigments produced by the insects. Rather than acting as a chemical deterrent for the macro environment of predatory insects, it could be possible the most significant effect of the pigments is in the microbial environment of the insect, deterring infection by bacteria and fungi, particularly the fungi that grow on the honeydew produced by the scale insects that the attending ants may miss. Because much of this recent research into medical applications seems widespread and promising, there may also be significant funding available to continue this type of research. One can hope that the research in

this tangential field of medicine can provide answers to broaden the understanding of the entomology, especially the entomology, ecology and biochemistry of the species of lac that live in the Sonoran Desert.

CHAPTER 7

Techniques and Advancements in Material Characterization for Verification of Insect Lac found in Artifact Collections

Introduction

Analyses of the material composition of artifacts in museums seek to provide evidence of their physical and chemical properties, their age and origin, and how these attributes might change through time (Szczepanowska 2013). Defining the material components of artifacts informs how one might expect that material to behave under different environmental conditions in order to implement the best practices to insure that artifact's long term preservation. For example, pine resin, which was used to waterproof basketry by some cultural groups in the arid Southwest, oxidizes and deteriorates, ultimately detaching from the basket due to excessive temperatures, pollutants and exposure to UV light (Odegaard et al., 2014). Being able to correctly identify pine resin and understanding its behavior informs museum preventive care in terms of conditions for exhibition and storage, and potential requirements for more interventive conservation treatment protocols. The same is true for the need to correctly identify insect lac as a different resinous component found in collections of cultural artifacts from the arid Southwest.

Insect lac in museum collections was frequently misidentified as a gum, pitch, or generic resin as described in detail in Chapter 3. As a polyester oligomer, its chemical and physical characteristics differ from plant based resins like pine pitch. With oxidation, lac often chemically cross-links, becoming less soluble and more rigid, unlike pine resin, which tends to yellow and crumble (Bisulca et al., 2017). Understanding the physical and chemical attributes of *Tachardiella* used in cultural material from the arid Southwest can help clarify the manufacturing techniques involved in artifact production, whether as a hafting adhesive or a mosaic mastic, as examples. Understanding how those attributes behave over time with different

environmental conditions can help to determine the best protocols for long term preservation in a museum context. The quest for characterizing lac as a material used in cultural heritage in the arid Southwest has a long history.

Harold Colton (1941) initiated the first intensive study of insect lac (*Tachardiella* spp.) in the American Southwest in the early 1940s after finding that it had cultural use by indigenous people of the region through time. He sent lac samples found at the Ridge Ruin site out for analysis to Volney Jones at the University of Michigan and fresh *T. larreae* samples to the National Paint, Varnish and Lacquer Association both who used microchemical tests to analyze the material (McGregor 1941:260; Westgate 1943). After synthetic plastics became available for commercial use not long after Colton's work, interest in lac research waned until the 1990's when a group of chemists and anthropologists studied plant and insect resin use by some of the Great Basin cultures. They published their work on chemical characterization of lac and other adhesives, sampling from archaeological museum collections and making comparisons to known samples (Fox and Sutton, 1995; Stacey and Sutton, 1998). Fox and Sutton (1995:367) sampled eight objects and used GC-MS (Gas Chromatography and Mass Spectrometry) for analysis. Stacey and Sutton (1998:59) sampled and analyzed five objects, also using GC-MS for analysis. In both studies the sample size was extremely small, and their results could not be generalized. They did determine many of the physical properties and most of the chemical composition of *Tachardiella larreae*, however, a very useful set of data to have.

A study of creosote lac (*Tachardiella larreae)* used as a repair material in the ethnographic pottery collections of the Arizona State Museum (ASM) employed FTIR (Fourier Transform Infrared Spectrometry) analysis taken from twenty-five vessels, another case study with a small sample size (Shackle et al., 2009). Unlike prior projects, these authors employed

ethnographic interview to supplement their research. Their interview with Mr. Joseph Joaquin, a Tohono O'odham cultural resource specialist provided excellent context regarding the techniques and uses of lac by his people (Shackle et al., 2009:27). During the survey of the much larger whole pottery collection of approximately 20,000 vessels, the ASM Conservation lab utilized a combination of microchemical tests, UV light examination and FTIR to study the variety of adhesives and other materials used on the objects (Unruh et al., 2005; White et al., 2009).

Another study by Stacey and Cartwright (2009) focused on the characterization of plant resins used as mastics for Mexican archaeological turquoise mosaic artifacts found in museums. Their study sampled resins from nine artifacts, another small sample. They determined that mixtures of different materials were used in combination to acquire different properties than a single resin could provide. They also improved our understanding how different resin adhesives functioned with diverse mosaic substrates, such as wood or shell (Stacey and Cartwright 2009:64). These researchers were interested in identifying the resins used on the artifacts believing the results would improve understanding of technology, distribution, and patterns of exchange. Their results only partly filled that gap in research. While their research succeeded in addressing material characterization, the results were generic, not detailed as to which species of lac insect was used (Stacey and Sutton, 1998).

All these earlier studies provided an excellent foundation on which to build this research project. The research design shares similarities with the others in that it has been based on analyses of resins found in museum collections, specifically on lac resin, and has employed similar analytical tools for extracting data. The first research goal here was to analyze resins found in museum collections and determine their composition, whether a polysaccharide (gum), diterpenoid (plant resin), insect lac or something else. A larger goal was to address the gap in

research to identify *Tachardiella* species from samples with these analyses, which could potentially improve our knowledge of the distribution of the insects used for cultural materials. To further address that gap, a third goal was to compare the chemical compositions of two species of *Tachardiella* that were freshly obtained from the field to identify similarities and differences. This chapter provides descriptions of the analytical techniques that have been used by researchers to characterize the chemistry and physical properties of lac, including raw lac and processed shellac. These techniques include microscopy, microchemical testing, UV light examination, FTIR, and GC-MS, all which were used to characterize resins found in artifact collections from the Arizona State Museum between 2005 to 2022. Most recently, GC-MS analysis was run on samples of two *Tachardiella* species collected in the field for comparison with samples identified as lac previously extracted from four artifacts, ethnographic and archaeological, in ASM collections. The sample size was limited by funding for analysis and by the numbers of samples available for testing from prior requests. The results of these analyses are provided in tabular and graphic form along with discussion.

Analytical techniques

Microscopy, microchemical testing and ultraviolet light examination

Early shellac analysis was based on microscopy and microchemical testing for solubility and characterization (Gardner and Whitmore 1929; Weinberger 1938, Westgate 1943). Table14 shows the chemical class component determinations for both Indian and American insect lac resin known at the time. Bose et al. (1963) provided a useful history of early chemical and physical analysis of shellac. Indian scientists began to isolate the complex chemical compounds of Indian shellac in the 1960s, using wet chemistry followed by gas liquid chromatography

(Singh et al., 1969), resulting in the definition of the chemical formula and structure of pure lac resin (Singh et al., 1974).

Table 15: Comparison of chemical composition of *Tachardiella larreae* and *Kerria lacca* Sources: (Westgate 1943; Wadia et al., 1969).

Chemical Components	*Tachardiella larreae*	*Kerria lacca*
Resin	23.5%	70-80%
Wax	51.9%	6-7%
Pigment	4.7%	4-8%
Other material	13-20%	15-25%

Microchemical tests have continued to be useful tools for analysis of art and artifacts containing resinous materials like lac. These tests have been applied in the field where access to lab equipment is not possible, or when the cost of obtaining equipment is not feasible in the lab (Odegaard et al., 2000; Burnell and Sutton 2019). Microchemical tests have supplemented other types of analysis for further confirmation, as with the ASM pottery project discussed above. Bisulca et al., (2018) described using microchemical tests to supplement the results of lac and plant exudate analysis along with examination with UV light and sample analysis with FTIR of ASM collections. Bisulca developed a new microchemical test for lac as part of this analysis (2018: 223):

> To test for the presence of unprocessed insect lac, a new chemical test was devised. A sample about the size of the head of a pinhead was allowed to soak in two to three drops of 1.0M sodium hydroxide (NaOH). A purple color in the sample or surrounding solution indicates a positive for lac because the unprocessed exudate contains anthraquinone dyes that change color depending on pH.

The combination of microchemical tests and FTIR analysis were also able to reveal the less consistently reliable results from ultraviolet (UV) light analysis alone. Bose (1963) reported that lac fluorescence, which revealed an orange color under long wave UVA light (315-400 nm),

was understood as early as 1928. Using UV light has been an inexpensive and expedient technique to screen multiple objects to determine if a resin was present, particularly if the resin was not heavily cooked or aged to the point where the dye chemicals had degraded, or were heavily soiled, and no longer properly fluoresced. UV analysis alone, especially of archaeological materials, were not found to be consistently reliable (Bisulca et al., 2018:228). Sarkar and Shrivastava (2000b) stated that lac resin was very resistant to long wave radiation but deteriorated from photo-degradation with short wave radiation. Measday (2017) reported that shellac that had been exposed to excessive UV from sunlight could fluoresce a yellow green color, more commonly seen with cellulose nitrate adhesive or aged pine resin. In these instances, UV light examination should only indicate the presence of a material that requires further analysis for reliable results. Nevertheless, many of the images presented in chapters 3 and 4 show examples of a strong positive indication for lac under UVA light. Most of those from ASM were confirmed with FTIR and microchemical tests also. Where sampling was not allowed, as with the National Park Service, UV light combined with digital microscopy were the only tools available for analysis at the time.

Fourier Transform Infrared Spectrometry (FTIR)

The examination of infrared light and its interaction with matter is infrared spectroscopy. The measurement of those interactions results in unique spectra which can be used to characterize or identify unknown materials, creating a spectral pattern like a fingerprint, which can be compared with a library of known spectra. The tool used to measure the spectra is called a spectrometer. The FTIR incorporates an interferometer which allows for better resolution among other improvements. Once the mathematics were developed to “transform” an interferogram to a

spectrum in the mid 1960s and later, computer technology advanced enough to process the data, FTIR became a standard analytical tool (Derrick et al., 1999). In time, computer technology improved and the cost of analytical equipment for FTIR decreased, while conservators' understanding of organic materials in art and archaeology and their degradation processes increased. The ASM Conservation Lab acquired its first FTIR spectrometer at the onset of the Pottery Project in the early 2000s.

The analysis of lac resin (*Kerria lacca*) using FTIR has been reported by Sarkar and Shrivastava (1997, 2000a, 2000b) and Sarkar and Kumar (2001), concerning characterization of different chemical forms of the resin and its degradation. Others have used FTIR to characterize a variety of natural resins, sometimes including lac (Martin-Ramos et al., 2018) or examination of Bursera resins found in Aztec cultural materials (Pina-Torres et al., 2018). The analysis of lac resin (*Tachardiella* spp.) with FTIR has been reported by Bisulca et al., (2017, 2018, 2019).

Gas Chromatography and Mass Spectrometry (GC-MS)

Gas chromatography is an analytical technique that uses a capillary column to separate the molecules of a sample. The molecules come off the column at different times, called retention times, allowing the mass spectrometer to break down each molecule into ionized fragments and detect them separately by mass and measured by intensity (Mills and White 2012). It is an analytical tool that can identify a multitude of compounds within a sample. In contrast, FTIR spectra show the absorption bands of functional groups, identifying the sample in complete form. GC-MS shows all the building blocks of that sample, all the chemical compounds of which it is composed.

The use of GC-MS to analyze shellac has been published extensively, in India where it is commercially produced and in the West due to shellac's use as a varnish on paintings, furniture and many other objects of art and antiquity. Lac is described as a complex mixture or composite of polar and non-polar elements, a "polyester resin made of inter and intra esters of polyhydroxy carboxylic acids formed from certain hydroxy acids and sesquiterpene acids" Sharma et al. (1983:262). The primary components of lac are the insoluble aliphatic acids, aleuritic acid being the most abundant and butolic acid, and terpenic acids, which are water soluble. Jalaric acid and Laccijaliric acid are two of the terpenic acids (Sharma et al, 1983:263). The authors also reported that the orientation of the polar groups give lac the characteristic of strong adhesion, making it an excellent binding agent. They describe lac further as a natural resin composed of "polyesters (estolides) of hydroxy long chain and sesquiterpenic acids and their oligomers…the average lac 'molecule', or repeating unit, has one free carboxyl, five hydroxyls, an aldehyde group and a point of unsaturation" Sarkar and Shrivastava (1997:370).

Others noted complications in examining shellac samples from different origins with slight differences in chemistry using GC-MS with pretreatment chemicals used for sample separation due to its complexity and the resulting constituents "such as terpenic acid, hydroxy fatty acids, and wax components present in shellac resins" (Wang 1999:1322). Coelho et al. (2012) also noted that the macromolecular nature of shellac made it difficult to characterize. Their analysis found that shellac's tendency to chemically crosslink due to natural and artificial ageing, resulting in reduced solubility, correlated to the aleuritic acid component of the resin. Sutherland and Del Rio (2014) also discusses the challenges of characterizing shellac with GC-MS and found that using quaternary ammonium methylating reagent (TMTFTH) was an effective derivatization pretreatment chemical, with results showing a characteristic derivatized

aliphatic and terpene acids. Their study analyzed over forty lac reference samples ranging from sticklac to various forms of processed shellacs from both India and Thailand. They also analyzed historic shellacs that had been employed as painting and furniture varnishes. The results showed that the composition of aliphatic hydroxyacids in lac varied depending on factors like the biological source of the resin. So, one would certainly expect variations between lac resins from different species of insects, an even from the same species but from different locations. They also found that unprocessed lac, sticklac and heated lac, with retained waxes, are easily identified by the presence of methyl ethers of fatty alcohols.

An early study of *Tachardiella larreae* using GC-MS was reported by Sutton et al. (1987) when a resin on a hermetically sealed jar from Southcott Cave in eastern Mojave Desert was identified as lac from the creosote bush. In another study, Fox et al. (1995) sampled resins from eight archaeological and ethnographic objects, four baskets and four pots, and analyzed them using GC-MS. They noted the lack of any prior studies of the composition of *Tachardiella* spp. The main peaks identified in their study consisted of: tetradecanoic acid (myristic), hexadecenoic acid (palmitic), 7-hydroxytetradecanoic acid, and 7-hydroxyhexadecanoic acid, the last being found as the principal constituent (Fox et al., 1995). They also found that aged samples of lac resulted in numerous unresolved components. The analysis confirmed that the sealant and repair resins on the four pots were all composed of insect lac.

Following the work of Fox et al (1995), Stacey et al. (1998) sought to study *Tachardiella larreae* further using GC-MS, hoping to identify more of the chemical components and to improve the "fingerprint" of the material for future analysis. The authors felt that identification of lac would facilitate anthropological studies of distribution, exchange, and material technology, an idea that initially influenced the goals of the present research. The GC-MS analysis was

conducted on two of five samples consisting of raw sticklac, three samples of melted raw lac, and an archaeological sample from a resin adhered to a crystal from Newberry Cave in the Mojave Valley. Their results produced a greater number of identifiable compounds than prior studies, adding octacosan -1-ol, triacontan-1-ol, dotriacontan-1-ol and tetratriacontane-1-ol to the list along with two possible unsaturated hydroxy fatty acids. The archaeological sample was also confirmed to be lac. Since this 1998 study, no further GC-MS analysis has been reported on *Tachardiella larreae*, and no study has yet been reported on *Tachardiella fulgens*, until this analytical research reported below.

Lac Analysis from 2005-2017

As discussed previously, the ASM Save Americas Treasures Pottery Project, which ran from 2002 to 2012, during which approximately 20,000 whole pottery vessels from the Southwest, both archaeological and ethnographic, were surveyed and relocated to state-of-the-art storage. As part of the survey process, previous repairs with adhesives were analyzed between 2005 and 2008 with UVA light, microchemical tests, and FTIR, described in detail by White et al. (2009:18). From that analysis 33 pots were confirmed to have "creosote lac" resins out of 6,500 vessels found with adhesives. White et al. (2009) found that 98% of all adhesive repairs were modern and 130 vessels had native repairs, 25% of those native repairs included lac.

ASM was awarded another Save Americas Treasures grant for the Woven Wonders Basketry Project that ran from 2012 to 2022, surveying and relocating to new state of the art storage more than 4,000 ethnographic baskets, 150 Southwestern cradleboards, 50 Northern Mexican hats, 48 barkcloths and woven mats, and over 32,000 archaeological perishable objects, including botanicals. During the inventory and rehousing of the archaeological perishables between 2015

and 2019, many examples of resinous adhesive materials were found that were poorly identified or unidentified in the catalog records. Bisulca et al. (2017:277) reported on the results of the analysis of 127 artifacts, 31 of which included insect lac. Analysis included UVA light, microchemical tests, and FTIR. From 2017 to 2021 I obtained permission to sample an additional 48 ethnographic artifacts found with unidentified adhesive resins in ASM collections, of which 25 contained insect lac.

Lac Analysis from 2017-2022

The analytical methods, materials, and equipment for both the projects described above are reported in White et al. (2009) and Bisulca et al. (2017, 2018). The analytical methods, materials, and equipment I used from 2017 to 2022 are as follows. The methods, materials and equipment used with ASM artifacts are identical to those described in Bisulca et al. (2017, 2018). The equipment used for UVA and microscopy differed when examining artifacts at sites other than ASM, using my own equipment instead. All FTIR analysis took place in the ASM Conservation lab. All GC-MS analysis took place at the University of Arizona Analytical & Biological Mass Spectrometry (ABMS) Facility.

UVA

While examining artifacts under UV light in the ASM Conservation I used the Blak-Ray B-100A 365 nm long wave and Entela UVLM 28 365 nm long wave units in the photography area of the lab with black out curtains. The darker the space, the better the results for UVA analysis. When examining artifacts at WACC and the Amerind I used my own Entela UVGL-55 Handheld lamp 254/365nm short and long wave, using

long wave. At WACC I put the objects inside a large box which I blacked out with black fabric over the box and my head while examining with UVA light. At the Amerind, I was only able to have lights turned off in most of the storage area, so it was not a full black out condition. All UVA images were taken with a Canon digital camera or the Dino-light image capture function as shown in (Fig 54).

Microscopy

In the sampling process at ASM, once permission to sample was received, a Dino-lite DinoXcope attached to Olympus SZ-PT Stereozoom Microscope was used to document with digital photography the object prior to sampling, during the sampling process, and to digitally photograph again after sampling. Where sampling was not permitted, a Digital USB microscope Dino-Lite Premier series (10x - 230x) with Mac laptop and Dino-lite software, and ProScope micro mobile digital microscope attached to an iPhone internal camera were used to take photographs with and without UV light for enhanced visibility during observations.

ATR-FTIR

All FTIR analysis was performed in the ASM Conservation analytical lab using a Thermo-Nicolet iS10 spectrometer with a Smart-iTR attachment, equipped with a He-Ne laser and deuterated triglycine sulfate (DTGS) detector. Small samples (~5–10 mg) were taken from artifacts for analysis using hand tools under a microscope as described earlier, with digital photography to document the process. Spectra were recorded in reflection mode from 4000 to 650 cm−1, with 64 scans at 4 cm−1 resolution. Identification was achieved by comparison with internal reference spectral database as well as other

commercial libraries including the Infrared and Raman User Group's database (iRug). OMNIC software was used to produce the spectra (Bisulca et al., 2017).

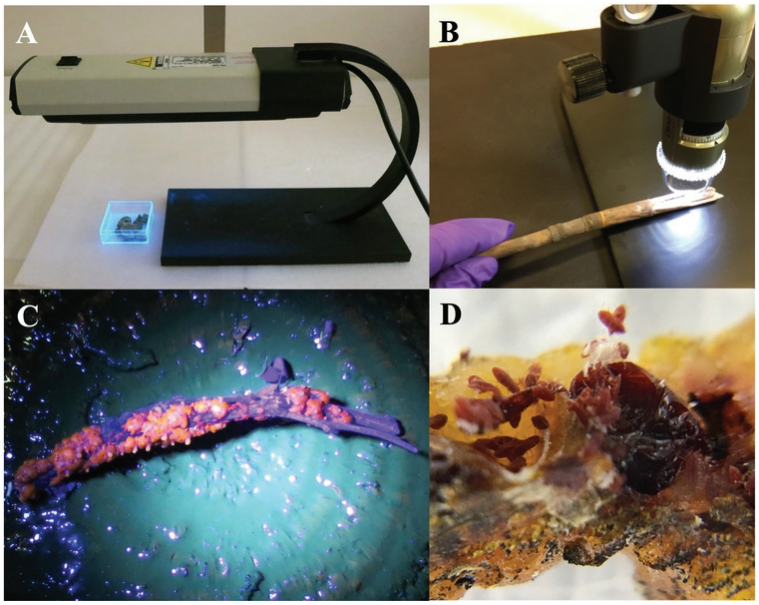

Figure 55 A Examination of objects with UVA light **B** Examination of object using Dino-Lite microscope **C** Fresh *Tachardiella fulgens* sticklac and fresh pine pitch coated basket under UVA light **D** *Tachardiella fulgens* hatching while viewed under Proscope™ digital microscope on iPhone

GC-MS

In August 2022, I submitted six samples for GC-MS analysis at the University of Arizona Analytical & Biological Mass Spectrometry (ABMS) Facility. The six samples included four samples of retained lac already collected with permission from archaeological artifacts from ASM that were initially analyzed in the ASM conservation lab using FTIR (Fourier Transform Infrared Spectroscopy), and two samples of raw sticklac I collected in the field. The *T. larreae* was a gift from a friend and community member, Anthony Sweezy, from San Xavier, where he found it growing on *Larrea tridentata*. The *T. fulgens* I collected from *Coursetia glandulosa*, growing in Sabino Canyon.

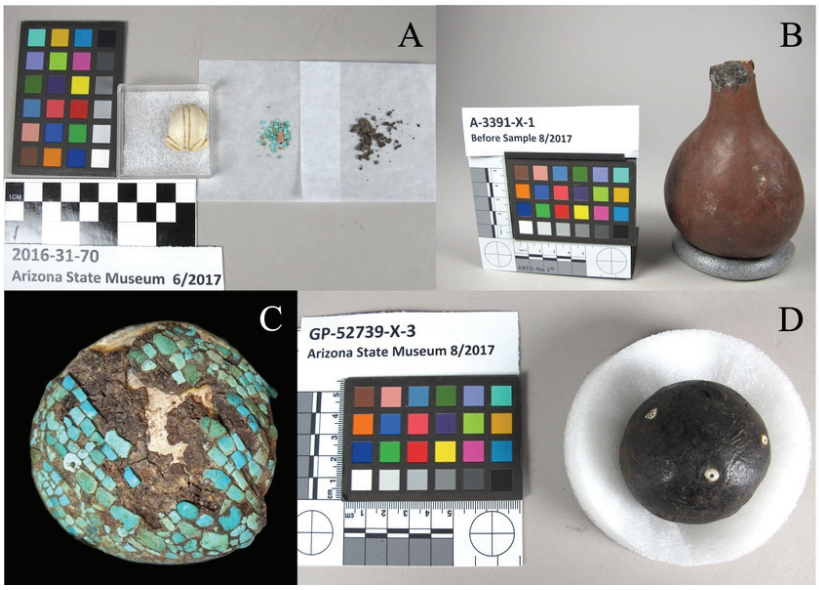

Figure 56 Artifacts sampled for both FTIR and GC-MS analysis. **A** Frog mosaic, Homol'ovi I, ASM#2016-31-70 **B** Gourd bottle with sealant ASM#A-3391-X-1 **C** Frog mosaic, Sinaguan, ASM#GP-5765 **D** Lac coated ball, Akimel O'odham ASM#GP52739-X-3

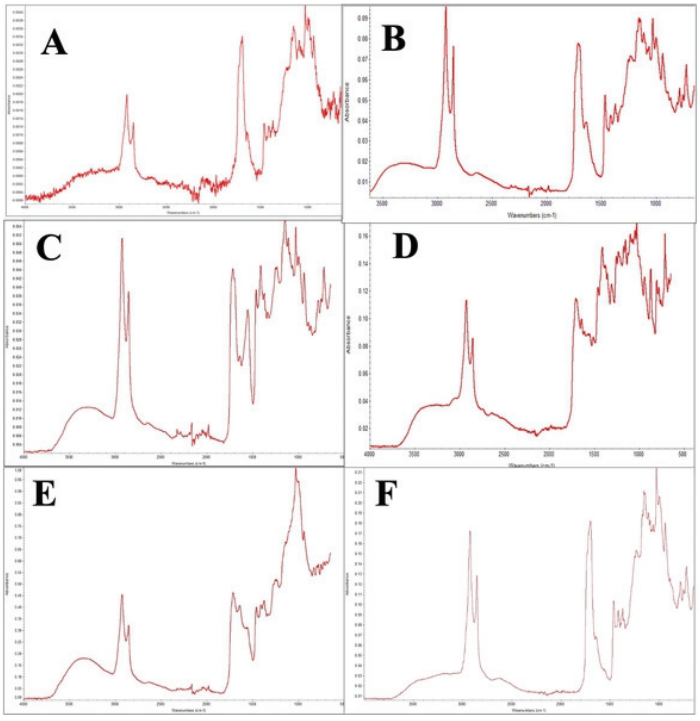

Figure 57 FTIR spectra from six samples also analyzed with GC-MS. **A** *Tachardiella larreae*, raw sticklac **B** *Tachardiella fulgens*, raw sticklac **C** Frog mosaic, Homol'ovi I, ASM# 2016-31-70 **D** Gourd bottle with sealant ASM#A-3391-X-1 **E** Frog mosaic, Sinaguan, ASM#GP-5765 **F** Lac coated ball, Akimel O'odham ASM#GP52739-X-3

GC-MS AMBS methods and materials

The procedures for analysis at AMBS were as follows. The samples were crushed to increase surface area for dissolution and weighed out to approximately 1mg each to normalize the peaks as much as possible. The samples were placed in a v-shaped 1.8mL glass vial with 100µl of toluene and 100µl of 3-(Trifluoromethyl)phenyltrimethylammonium hydroxide (m-TFPTAH) and allowed to react at room temperature overnight. A blank of 100µl toluene and 100µl m-TFPTAH that was treated in the same way as the samples to get the background peaks. None of the samples dissolved completely, so were spun down to move undissolved material to the bottom of the vial. 100µl of the supernatant was transferred to a 200µl glass insert in a 2mL glass vial and1µl was injected for each sample and the blank.

Materials for GC-MS

Solvents:
3-(Trifluoromethyl)phenyltrimethylammonium hydroxide (5% w/v in methanol) from Thermo Scientific; Toluene (99.85%, extra dry over molecular sieve) from Acros.

Equipment:
The instrument was a Shimadzu GC2010 gas chromatograph, coupled to a Shimadzu GCMS-QP2010S mass spectrometer, with a Shimadzu AOC-20i autosampler. The column was an Agilent DB-5, 30m x 0.25mm x 0.25 um (length x diameter x film thickness).

Table 16: Parameters of GC-MS equipment used in analysis

Mass spec method parameters:	
	Injection temp: 300°C Splitless mode Sampling time 0.7 min Pressure: 90.7 kPa Total Flow:16.4 mL/min Column Flow: 1.54 mL/min Linear Velocity: 45 cm/s Purge Flow: 3.0 mL/min
Mass spec parameters:	
	Mass range: 50-750 m/z Ion Source Temp.: 230°C Interface Temp.: 280°C Solvent cut time: 5 minutes Detector Voltage +0.2kV relative to tuning voltage (0.87kV) Mass range: 50-750 m/z
Chromatographic method:	
	50°C initial temp, hold for 2 minutes Increase temperature 10°C/min until 310°C Hold at 310°C for 12 minutes

Results of GC-MS

The analytical data were provided in bulk raw form in a spreadsheet and in graphic form in a series of chromagrams for each sample based on set amounts of retention times to make the peak compounds more visible. These data revealed the following number of detected compounds per sample.

Table 17: Samples used for GC-MS analysis and resulting compounds per sample

Sample	Description	Number of Detected Compounds
Tachardiella larreae	Raw sticklac	141
Tachardiella fulgens	Raw sticklac	112
2016-31-70	Frog Effigy Mosaic mastic Homol'ovi I, 1285-1400 CE	116
A-3391-X-1	Bottle gourd with sealant, Prehistoric Rio Sonora	107
GP-5765	Frog Effigy Mosaic mastic, Sinagua Chevelon/Chavez Province 1300-1400 CE	52
GP-52739-X-3	Ball with lac coating, Akimel O'odham, Snaketown area, c. 1934 CE	146

I cross referenced all the chemical compounds found in all six samples and listed where there were matches in the table below. The samples from artifacts had been processed for use with heat, and in some cases possible added materials, especially in the mosaic from Chevelon/Chavez Pass. With the application of heat and effects of ageing, the chemistry of the archaeological samples differed from the fresh samples in that respect. All the samples contained long chain fatty acid esters, indicative of the high wax content of the *Tachardiella* spp. lac found in the arid Southwest. It was also interesting the variation in compounds between the two species of lac, *T. larreae* and *T. fulgens*. GC-MS results for *T. fulgens* have never been published, so this analysis will be important for Southwest entomology in addition to improving the understanding of its cultural use in the region.

Table 18: Chemical compounds found among the six samples analyzed by GC-MS

Chemical Compound	2016-31-70	GP-5765	A-3391	GP-52739	T. larreae	T. fulgens
Benzenebutanoic acid, 2,5-dimethyl-, methyl ester		√		√		
Benzenepropanoic acid, 2-methoxy-, methyl ester	√		√			
Benzoic acid, 3-(dimethylamino)-, methyl ester	√	√				√
Docosane			√		√	√
Dodecanedioic acid, dimethyl ester	√				√	
Heneicosane	√	√	√			
Hexadecanoic acid, methyl ester				√	√	√
Hexanedioic acid, dimethyl ester			√	√	√	
Methyl tetradecanoate			√	√	√	√
N-Methyldodecanamide	√	√				
Nonanedioic acid, dimethyl ester	√	√	√	√	√	√
Nonanoic acid, methyl ester	√			√		
Octacosanoic acid, methyl ester	√		√	√	√	√
Octanedioic acid, dimethyl ester	√		√	√	√	
Pentadecanoic acid, methyl ester	√		√	√	√	√
Pimelic acid dihydrazide	√			√	√	
Tetracosanoic acid, methyl ester	√			√	√	
Tetratetracontane	√	√	√	√	√	√
Triacontanoic acid, methyl ester			√	√	√	

Chromatograms Tachardiella spp.

The following set of figures and tables illustrate the chromatograms and peak compounds shown for the retention time of 15-20 minutes for each of the samples of *T. larreae* and *T. fulgens* for comparative purposes. The total retention time for each sample extended approximately 36-40 minutes and the 15-20 minute period for both samples had the most notable peaks in the entire period, hence the choice to isolate that part of the graph. As noted earlier, GC-MS analysis of *T. fulgens* has never been published. The tables below each figure provide the chemical compounds represented at each peak in the chromatogram, with each associated retention time. Chromatograms were also produced from the four artifact samples. They are excluded here because of the difficulty in interpreting the data since there are so many complex factors involved, such as possible added materials in the case of GP-5765 and variations in states of degradation due to ageing and their individual site histories. In contrast, the raw lac samples are unadulterated and relatively fresh.

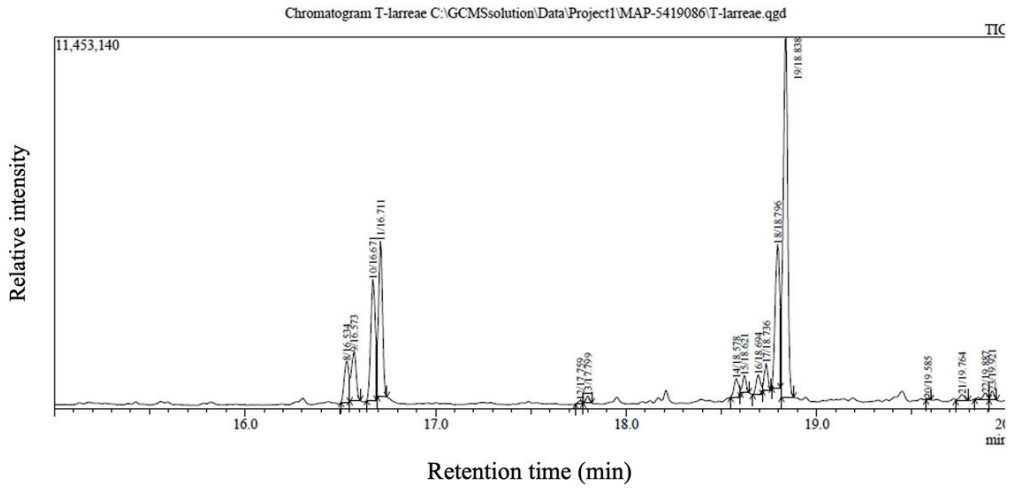

Figure 58 Chromatogram for *Tachardiella larreae*, raw sticklac, ret. time: 15-20 min.

Table 19: Compounds detected in *Tachardiella larreae* raw sticklac, ret. time: 15-20 min.

Peak #	Retention Time	Compound Name
8	16.535	9-Hexadecenoic acid, methyl ester, (Z)-
9	16.575	9-Hexadecenoic acid, methyl ester, (Z)-
10	16.67	Methyl tetradecanoate
11	16.71	Methyl tetradecanoate
12	17.76	Pentadecanoic acid, methyl ester
13	17.8	Pentadecanoic acid, methyl ester
14	18.58	9-Hexadecenoic acid, methyl ester, (Z)-
15	18.62	9-Hexadecenoic acid, methyl ester, (Z)-
16	18.695	2-Hexenoic acid, 2-methyl-
17	18.735	6-Hydroxy-8-methoxyoctanoic acid, methyl ester
18	18.795	Hexadecanoic acid, methyl ester
19	18.835	Hexadecanoic acid, methyl ester
20	19.585	Methyl pentadecyl ether
21	19.765	
22	19.885	3-Buten-2-ol, 2-methyl-4-(1,3,3-trimethyl-7-oxabicyclo[4.1.0]hept-2-yl)-
23	19.92	2-Cyclopenten-1-one, 4-hydroxy-3-methyl-2-(2,4-pentadienyl)-, (Z)-(+)-

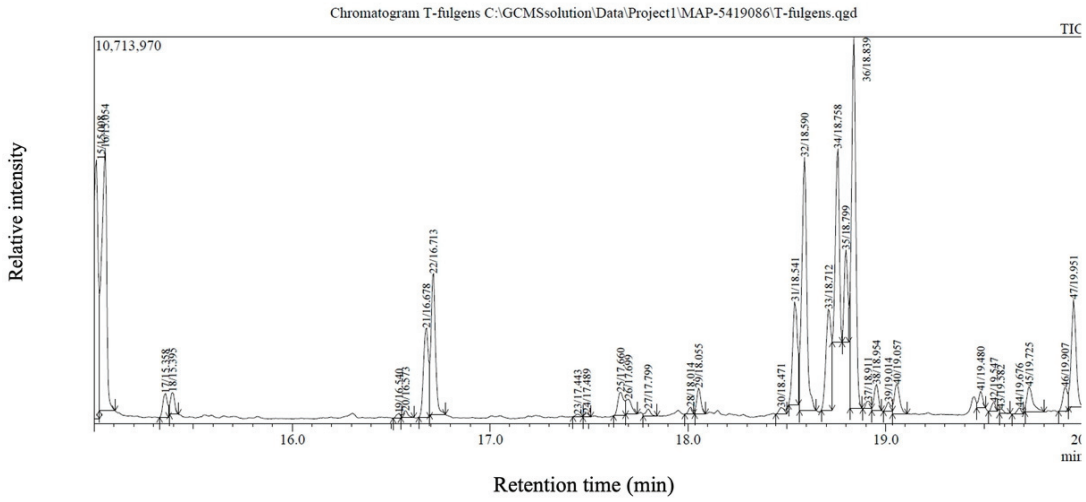

Figure 59 Chromatogram for *Tachardiella fulgens*, raw sticklac; ret. time 15-20 min.

Table 20: Compounds detected *Tachardiella fulgens*, raw sticklac; ret. time 15-20 min.

Peak #	Retention Time	Compound Name
16	15.055	Pyrrolidine-2-one-trans-4,5-dicarboxylic acid, dimethyl ester
17	15.36	Tridemorph
18	15.395	Tridemorph
19	16.54	9-Octadecenoic acid (Z)-, methyl ester
20	16.575	9-Hexadecenoic acid, methyl ester, (Z)-
21	16.68	Methyl tetradecanoate
22	16.715	Methyl tetradecanoate
23	17.445	8,11,14-Eicosatrienoic acid, methyl ester, (Z,Z,Z)-
24	17.49	Cyclopropaneoctanoic acid, 2-[[2-[(2-ethylcyclopropyl)methyl]cyclopropyl]methyl]-, methyl ester
25	17.66	
26	17.7	2-Methoxycarbonylmethyl-3-methylcyclopentanecarboxylic acid, methyl ester
27	17.8	Pentadecanoic acid, methyl ester
28	18.015	
29	18.055	Bicyclo[2.2.1]heptane-2-acetic acid, 5-methoxycarbonyl-, methyl ester
30	18.47	2H-3,9a-Methano-1-benzoxepin, octahydro-2,2,5a,9-tetramethyl-, [3R-(3.alpha.,5a.alpha.,9.alpha.,9a.alpha.)]-
31	18.54	2,6-Nonadienoic acid, 9-(3,3-dimethyloxiranyl)-3,7-dimethyl-, methyl ester, (E,E)-
32	18.59	2,6-Nonadienoic acid, 9-(3,3-dimethyloxiranyl)-3,7-dimethyl-, methyl ester, (E,E)-
33	18.71	Octadecanoic acid, 7-hydroxy-, methyl ester
34	18.76	Octadecanoic acid, 7-hydroxy-, methyl ester
35	18.8	Hexadecanoic acid, methyl ester
36	18.84	Hexadecanoic acid, methyl ester
37	18.91	2(3H)-Benzofuranone, hexahydro-7a-methyl-
38	18.955	2(3H)-Benzofuranone, hexahydro-7a-methyl-
39	19.015	2-Propen-1-amine, N-(phenylmethylene)-
40	19.055	2-Propen-1-amine, N-(phenylmethylene)-
41	19.48	Nerol, methyl ether
42	19.545	cis-Z-.alpha.-Bisabolene epoxide
43	19.58	
44	19.675	9-(3,3-Dimethyloxiran-2-yl)-2,7-dimethylnona-2,6-dien-1-ol

Discussion

Running GC-MS analysis of the two raw samples of lac was useful for determining a greater number of chemical compounds than had been previously published on *T. larreae* (Stacey et al., 1998). It was also interesting that results show there are seven shared compounds between the two species, and there are many more compounds that are not shared between the two. As anticipated, the results from the four lac samples taken from artifacts were obscure and difficult to interpret due to their complex histories and their possible variation in materials. The results of this analysis confirm that lac is a very complex matrix of chemicals and that artifact based lac requires a different kind of analysis for more conclusive results. The quest to fill gaps in comparing different species of *Tachardiella* has started but far more work remains to find satisfactory answers.

Future analysis

A technique that has been used to characterize shellac, without the clarification difficulties found with GC-MS, is High Pressure Liquid Chromatography (HPLC). Tamburini et al. (2017) found that HPLC combined with electrospray ionization (ESI) and quadrupole time of flight detection (Q-ToF) provided very accurate compound separation with accurate masses assigned. They were able to identify different isomers and oxidation products also. It is a technique that provides greater accuracy and clarity for shellac than GC-MS. The cost of lab analysis is also very expensive, significantly more than GC-MS.

The trend today for Conservators and Conservation Scientists for material characterization of cultural material components is towards minimally invasive to non-destructive sampling for analytical techniques, especially with sensitive cultural materials, both archaeological and historic. Recently published techniques for sampling include using 6 μm

diamond microgrit polishing films, as Gilbert et al. (2021) did with analysis of archaeological bone. Richter et al. (2022) describe sampling proteinaceous materials using polyvinyl erasers, successfully used to sample parchment and bone for use in zooarchaeology by mass spectrometry (ZooMS), also called matrix-assisted laser desorption/ionization time-of-flight mass spectrometry, to identify collagen for peptide mass fingerprinting. Barberis et al. (2017) report on a non-invasive technique to sample proteinaceous art materials from surfaces by adsorption using functionalized films made with a mixture of resin and ethyl-vinyl acetate (EVA). Multari et al. (2022) describe proteomic analysis of Egyptian mummy skin, sampling with dermatological tape strips used in microbiological and biochemical sampling, a very minimally invasive technique. It would be interesting to test some of these sampling techniques on raw, processed, and aged *Tachardiella* spp. samples and run them through various analytical processes for comparison to results from other more invasive sampling techniques and to determine their efficacy.

Even though FTIR, GC-MS and HPLC use minute samples, they still require the removal of a non-renewable cultural resource, which is destroyed during the analytical process. As discussed earlier, museums and repositories often have stringent rules regarding permission for sampling, or do not allow any sampling at all, ruling out several analytical options. Raman spectroscopic analysis is a non-destructive technique that has been used to characterize Mexican artist materials, including scale insect produced *aje* used to make *laca*, for example (Vandenabeele et al., 2007). Edwards and Falk (1997) used Raman to analyze some of the same artifacts analyzed by Fox and Sutton (1995) with GC-MS. Daher and Bellot-Gurlet (2013) successfully used Raman to analyze archaeological resins from Africa without destructive

sampling. While Raman can be problematic with fluorescent materials, it would be worth trying the technique with samples of lac in the future.

DNA analysis of the species of *Tachardiella* spp. found in the arid Southwest would be essential for generating genomic fingerprints for comparison to samples from artifacts whether by proteomics, or other analytical methods described above. It is possible that using HPLC would enable the creation of different fingerprints between the different species of *Tachardiella* by chemical composition alone. DNA analysis would add to the toolbox significantly. Additionally, to date, this analysis has not yet been published and with the availability of technology and acquiring the funding, it needs to be done in the future.

Conclusion

This chapter has summarized the analytical techniques used in the past to characterize lac resin, both shellac from *Kerria lacca* and lac from *T. larreae*. The chapter also described the analytical techniques used for material characterization of resins found in selected archaeological and ethnographic collections of the Arizona State Museum. Last year, funding was awarded to analyze six samples, examples of two raw lac species and four samples from ASM artifacts by GC-MS analysis. The four artifact samples had been confirmed to include insect lac with UVA light and FTIR.

This is the first time GC-MS analysis has been reported on both *T. larreae* and *T. fulgens* and the comparison of their chemical compositions. The number of compounds defined by the analysis for the two raw lac samples and the samples from artifacts were larger than previously found. Patterns were observed in comparing the sample results, but conclusions could not be drawn about the artifact samples given their various ages and the likely presence of many degradation products, particularly in the archaeological samples. It was difficult to determine if

there are other additives in the mosaic mastics, like beeswax or other resins. Further examination and testing will be required to come to conclusions about possible mixtures, but there are some compounds present that warrant further study, especially in the Sinaguan mosaic.

CHAPTER 8

Conclusion

Scholarship describing the use of lac scale exudates in the composition of archaeological and historic cultural materials in the arid Southwest by Colton, Euler and Jones in the 1940s and 1950s and Sutton, Fox and Stacey in the 1990s all left unanswered questions. The consensus of these studies was that lac from *Tachardiella* spp. could not compete as a commercial product with lac coming from Asia. There was curiosity about the quantity of lac in cultural material found above the Mogollon rim, in the Ancestral Puebloan region. All the scholars made assumptions about the distribution of the insects and the likelihood of exchange of the material. Sutton, Fox and Stacey believed that clarification of the relationships between insect species and host plants might improve understanding of technology, distribution, and patterns of exchange of lac. These studies piqued my curiosity, especially after seeing the quantities of lac used to coat kicking balls and some of the large lac based pottery repairs in the collections at the Arizona State Museum. Following the trail of questions left by previous scholars I sought to clarify the distribution of the three primary *Tachardiella* species that were used to fabricate artifacts and their host plants in the arid Southwest, followed with a larger exploration of the cultural use of the material than in previous studies and prior research conducted at the Arizona State Museum. I speculated that a comparison of the distribution of the insects with the distribution of its cultural use might elucidate greater understanding of patterns of exchange of lac and lac containing artifacts.

The purpose of this research has been to broaden the current understanding of the biology and ecology of lac insects in the arid Southwest to explain more about indigenous cultural uses and traditional ecological knowledge about these materials in the region over time. By

documenting known distributions of the insect, plant and manufactured material, data has been gathered for analysis to search for meaningful relationships. Ultimately, the biological and anthropological investigation of lac scale exudate sources, distribution, extent of use, and of possible circulation through trade has further illuminated its cultural significance. The data gathered has formed a foundation from which to expand research with further resources for more detailed biological and chemical analysis.

In chapter two I presented the results of the examination of the distribution of the three species of *Tachardiella* used in manufacturing of objects and their primary host plants as collected specimens and more recently as field observations. The distribution of the host plants has been well documented and well defined. Early collections of *Tachardiella* spp. were isolated and consisted of very few specimens. Specimen origin locations were rarely specific. See Appendix A for this data on entomological specimens. The wider distribution of *T. larreae* was initially documented throughout Arizona and partially in surrounding states in the 1940s. No known detailed published distribution studies exist on *T. fulgens* and *T. pustulata*. Since very few specimens appear to exist in entomological collections available online it was difficult to glean much from them about distribution beyond general areas. Contemporary observances using social media type applications filled in many gaps left by collected specimens, especially for *T. larreae*. There are localized observances of *T. fulgens* in Arizona and Sonora, Mexico. Access to what specimens may be in Sonoran entomology collections on-line is not yet available. There are very few specimens of *T. pustulata* in entomology collections and there are no contemporary observances to date. Further field work and research is required to define the distribution boundaries of *T. fulgens* and *T. pustulata*. Such studies would be helpful for both entomological and anthropological disciplines regarding *Tachardiella* spp. More detailed distribution studies of

all three species may also help explain their different environmental preferences, which physical factors contribute to their success, including specific elevations, temperatures, soil types, exposures, and topographies. Additional field research on each species' mutualistic relationship with ants is still required also.

In chapters three and four I examined the distribution of anthropological artifacts made with lac from *Tachardiella* spp. as well as entomological specimens cataloged among artifact collections. Initially, I assumed that use of a broad sample from a variety of different museums of various sizes and repositories would overcome the expected weakness of bias from collectors, and misinformation in documentation, which is more often a problem when using collections solely from a single institution. Larger urban and regional museums and repositories tend to house more systematically collected artifacts, which indicates that documentation would be more accurate and reliable, given they often have larger staff numbers devoted to identification and curation. That assumption was challenged in most institutional online research on *Tachardiella* lac, unfortunately. Most of the lac containing artifacts were collected prior to the mid-twentieth century when knowledge of lac was limited and misidentification and/or misnomers were prevalent. These limitations could be partially overcome by deciphering their terminology as shown in Table 9. Familiarity with the appearance of the material, backed with descriptions in the published record, along with biological samples obtained by the same collectors resulted in more probable to exact identifications. Appendices B and C contain details on the archaeological and ethnographic objects documented.

Many early collectors of both lac specimens and artifacts did not often provide detailed information about collection locations beyond regions of state levels in the United States and national level in Mexico. This was the case with both artifacts and specimens collected in Utah

for example, where the level of location detail was ‘South Utah’. Nevertheless, artifact analysis expanded the known distribution of *T. pustulata* into southern Nevada and southern Utah since the artifact collectors also collected specimens concurrently. Later, collectors provided more location detail for both artifacts and specimens so that the two types of lacs, artifacts and specimens, could be compared by locations.

Table 21: Distribution of lac containing artifacts and specimens by state and county.

State	Counties per state	Counties/Municipalities where lac containing artifacts found	Counties/Municipalities where lac specimens found/observed
Arizona	15	Apache, Cochise, Coconino, Gila, Graham, Navajo, Maricopa, Mohave Pima, Pinal, Yavapai, Yuma	Cochise, Graham, La Paz, Maricopa, Mohave, Pima, Pinal, Yavapai, Yuma
California	58	Imperial, Inyo, Riverside, San Bernadino, San Diego	Imperial, Inyo, Riverside, San Bernadino, San Diego
Nevada	17	Churchill, Clark, Washoe	Clark, Nye
New Mexico	33	Grant, San Juan	Dona Ana, Grant, Hidalgo, Luna, Otero
Texas	254	El Paso	El Paso, Presidio
Utah	29	San Juan, Wayne	S. Utah
Baja California	7	Ensenada	N/A
Chihuahua	67	Batopilas, Carichí	Batopilas, Polanco
Sonora	72	Caborca, Cumpas, Hermosillo, Onovas, Plutarco Elías Calles, San Luis Río Colorado	Alamos, Caborca, Cucurpe, Hermosillo, San Luis Río Colorado, San Jose de Guaymas

Arizona is the source for the largest numbers of archaeological and ethnographic objects containing lac of all the states studied to date (Table 25). This result is likely partly related to the accessibility of the collections at the Arizona State Museum to myself as a staff member to in person research over a period of several years, where other collections were accessible for a few days and most others were only accessible online. If in person research of artifact collections in California had been possible, the state where the largest number of *Tachardiella* specimens have been observed (Figure 8), the number of lac containing artifacts documented from the southern part of the state would probably be much higher. Hermetic sealing of pottery was known to be used in prehistoric communities in the Great Basin in eastern California, for example. Artifacts containing lac were collected and documented from twelve of Arizona's fifteen counties and lac specimens were collected or observed in nine. The three northern counties of Apache, Coconino and Navajo were all sources for lac containing artifacts though they had no lac specimens, indicating the lac likely came to the area either in the form of prefabricated artifacts made where lac was available, or the raw lac was brought in through exchange or perhaps both.

This research has expanded the previously known boundaries of the distribution of both the *Tachardiella* species and the peoples who utilized them to manufacture cultural materials in the arid Southwest. It was not previously known that *Tachardiella* spp. lived in Nevada, Utah and Texas and was exploited for manufacture of artifacts in those states. The extent of the habitat for *T. larreae* in New Mexico was also unknown. Insect lac exudate has been identified in Archaic, Basketmaker, Ancestral Puebloan, Sinagua, Mogollon, Hohokam, Salado and Patayan artifacts, suggesting prehistoric movement of this material throughout the cultural regions of Arizona, New Mexico, southern Nevada, southern Utah and northwest Texas. Lac is also found archaeologically in Sonora, Mexico among the Prehistoric Rio Sonoran, Prehistoric Comcáac

and Trincheras culture groups. Insect lac exudate has been found used in the historic era material culture of the Akimel O'odham, Cahuilla, Chemehuevi, Cocopah, Comcáac, Havasupai, Hualapai, Kumeyaay, Luiseño, Mayo, Mojave, Panamint, Northern Paiute, Southern Paiute (Kaibab, Moapa, Shivwits bands), Pima Bajo, Piipaash, Quechan, Tarahumara, Tohono O'odham, and Yaqui. The extent of cultural use of lac, both archaeologically and historically, was significantly expanded by this research, especially into California, Nevada, Texas and Utah.

Table 22: Distribution of lac containing archaeological and ethnographic artifacts by state.

Location found (state)	Number of lac containing archaeological objects	Number of lac containing ethnographic objects
Arizona	69	90
California	0	47
New Mexico	8	0
Nevada	4	7
Texas	1	0
Utah	18	10
Baja California, MX	0	3
Sonora, MX	5	66
Chihuahua, MX	1	4
Southwest Unknown	2	0

At the outset of this research, I made assumptions about the possible extent of exchange routes that could have been used to transport lac in the region, both in the prehistoric and historic eras following the lead of previous scholars. For the prehistoric era, I assumed raw lac was only available in the southern lower elevation parts of the region and that it would have been exchanged by the Hohokam to other people north above the Mogollon Rim and to the east to the

Mogollon and Chaco culture groups in New Mexico. My original hypothesis was to test whether lac was traded north and east from Sinaloa and Sonora, along with salt and shell, and acquired in Papagueria also, where shell was manufactured, and then traded north to the Gila River area on onwards as manufactured products. As data accumulated during research with revelations of broader physical distribution and range of *Tachardiella* spp. along with more extensive cultural use distribution of the material, initial assumptions about possible exchange routes used for both raw lac and objects manufactured with lac changed.

It is very likely that small and lightweight prestige objects made with lac such as etched shell and later mosaics made with lac mastic were manufactured in the Hohokam and Salado regions and exchanged to other areas to the north and east in manufactured form. The mosaic frog from Homol'ovi (Figure 26) is such an example. Other materials like those found at Ridge Ruin and other Sinaguan sites, and Chaco may have been locally manufactured with acquired raw lac. Raw lac was found at Ridge Ruin, for example. Further study will be required to be more certain. Learning that raw lac from the Colorado River, southern Nevada, and southern Utah was available to northern communities, potentially indicates that lac exchange was also taking place from west to east along northern corridors, as was shown in the historic era between the Havasupai and Hopi in Chapter 4.

Chapters 3 and 4 showed that some forms of lac containing artifacts made in the prehistoric era phased out of production by the historic era. These items included the prestige objects of etched shell, lac-based mosaics, inlaid jewelry, and ceremonial objects. Some utilitarian objects made with lac persisted through time, most in localized areas, such as the hafting material for arrows and knives, awls for basketry, lac coated balls, and hermetic sealant for pottery and gourds. In the historic era lac used for pottery repair becomes more common,

possibly better preserved and more commonly found, as does lac as the adhesive for gourd rattles. The Comcáac used lac to fill wood carvings at least until the 1970s if not longer. Other objects like the Comcáac lac amulets may have been made in the prehistoric era but have not been found or preserved to date.

In her chapter on craft specialization Costin (1991) states that all economic systems are comprised of the following: production, distribution, and consumption. Production is defined as the transformation of raw material into usable objects and the organization of production is based on three components: 1) distribution of raw materials, 2) nature of technology and 3) skills and training. Craft specialization is a way to organize the steps involved in producing objects from raw materials, and producers time, skills and other inputs in exchange for compensation of some kind. Production of objects is considered specialized when there are more consumers than producers of those objects. Costin (1991) suggests that producers depend on exchange relationships from outside the household for part of their subsistence and that consumers depend on the producers for acquisition of goods they do not create themselves, since not all households produce what they consume. Costin (1991) also focuses on the parameters of craft specialization in terms of 1) context - the spectrum of producers between independents and elite attached or sponsored specialists; 2) concentration – the range of geographic locations or distribution for production, including consideration of transportation of materials and goods; 3) scale – the labor input or number of people involved in production with consideration of efficiency; and 4) intensity – the time input by producers whether part time for supplemental income or full time full income with consideration of the roles of gender and division of labor.

The independent craft specialists tended to produce utilitarian goods consumed by local households. Examples of object types produced locally with lac would include wooden handles

with wads of lac on top for smearing after heating to repair for cracked pottery. Arrowheads hafted with lac were probably made locally by the men who used them. ASM collections contain both Hohokam and Akimel O'odham balls coated with lac used for running on the salt trails, all of which have significant quantities of the resin on the exterior. There had to have been access to equally significant amounts of raw material, likely locally acquired, to produce them. These kinds of objects did not require particularly specialized skills or a great deal of time to make. These objects could be produced anywhere the materials were accessible by essentially anyone.

Lac used for production of prestige goods like etched shell or mosaic ornaments are examples of objects that required a much higher degree of skill and time for production. Significantly less lac was used in these products than the utilitarian objects. According to Bayman (1999) these objects tended to be traded wide and far in part due to their light weight and small size. Degree of specialization in production can inform locality of production as indirect evidence according to Costin (1991). Not every community could produce highly specialized objects, which indirectly narrows down the manufacturing sites that had the ability. Costin (1991) suggests localized production could be determined by direct evidence, such as the presence of tools, remnant materials and debris. One might also be able to determine localized areas of production by sourcing the lac as a raw material.

Further study of the manufacturing sites and technologies for prestige objects like lac-based turquoise mosaic on shell and other substrates is needed. If the objects were made in Plateau, Rim or Mountainous communities then the lac was likely imported as a raw material. If made in the lowland deserts, the ceremonial objects were traded for themselves, not for the lac, even though the lac is also a rare enough material contributing to the object's social value. The lac used for utilitarian objects like knives and arrows was probably acquired raw and used in situ

to make the tools in the Mogollon region and elsewhere, but this also requires further study. The knowledge of the properties of the material, its superior strength compared to other organic adhesives available at the time, possibly preceded it, perhaps through other exchange networks or migration contacts.

The examination of cultural use of lac in the historic era in Chapters 4 and 5 revealed the persistent high social value of the material, plus its value as an adhesive until the introduction of synthetics. The use of lac as a repair and fabrication material for objects like broken pottery and gourd rattle handles declined and disappeared with the advent of inexpensive and readily available synthetic adhesives including white glues, super glues, hot glues, and epoxies. These modern adhesives were found through analysis in objects made or repaired from the 1970s onward where lac would have been used in the past. The knowledge of some of its former uses has faded as time progresses in the arid Southwest, as with the Comcáac for example.

Nevertheless, the cultural significance of lac remains embedded in the creation stories of the O'odham peoples. The traditional knowledge of lac is embedded in the Comcáac language. There are still basket weavers along the Colorado River who have been making their awls with lac. The Tarahumara still produce *Arí* with lac and restaurants in Chihuahua continue to serve it as a specialty condiment. Contemporary artists like Jacob Butler, Onk Akimel O'odham from the Salt-River Pima Maricopa Community, are revitalizing the arts of etched shell and mosaic making with lac as a component. Continued exploration and documentation of traditional ecological knowledge of lac in a broader context could revive possible meanings, perhaps long separated or lost, since the artifacts or belongings were collected, removed from their original contexts, and curated into deep storage, often misidentified, and forgotten. A goal of this aspect

of the research has been to facilitate exposure of information about lac found in museum and repository collections, to revive the material and its uses from obscurity.

Future research

Lac from the arid Southwest is a fascinating and unique material that deserves to be pulled out of obscurity further. More field work on the ecology of the three *Tachardiella* species in the arid Southwest and molecular phylogenetic analysis should be conducted, since inferences as to their evolutionary relationships with their host plants and associated chemical relationships continue to remain obscure. Their relationships with other organisms, such as mutualist ants, predators, and their microbiota also require study and description. Further research into the relationship between *Tachardiella* spp. and their microbial environment may contribute to new medical applications and could provide answers to broaden the understanding of the entomology, ecology and biochemistry of the species of lac that live in the arid Southwest. The distribution data presented in this research can provide a foundation from which further scientific research can emerge.

One set of researchers in Mexico utilized FTIR and high-performance liquid chromatography coupled to diode array detection (HPLC-DAD) along with multivariate statistical analysis to determine the botanical origin of resins to particular species of *Bursera* plants as the source of copal found used as adhesives and deposits in Aztecan archaeological objects (Pina-Torres et al., 2018). It could be possible to set up a similar study of lac resin used in artifacts using the HPLC-DAD if additional funding, expanding on and refining the GC-MS analysis conducted as part of this research. If the source of the species of lac could be determined, whether *T. larreae, T. fulgens, T. pustulata,* and the four other species growing in

North America, each species having mostly distinct host plants with particular ecological ranges, novel understanding could be possible by comparing where raw lac originated relative to the location the manufactured product was discovered. This information would provide a better understanding of how far the material moved from source to ultimate destination. For example, if *T. larrea* was rare and difficult to procure, as described in Colton's study, it may have been that the primary source for lac for trade was instead *T. fulgens* from Sonora and the Tucson Basin and/or *T. pustulata* from the Colorado River region and southern Utah, depending on where the endpoint of exchange concluded. This research has been a revival and expansion of the documentation and scholarship performed previously by other researchers and provides a foundation from which further explorations of insect and plant exudates used in the arid Southwest region will continue.

SUPPLEMENTAL MATERIALS

APPENDIX A

Entomological Specimens of *Tachardiella* spp.

Institution	Catalog No.	Scientific Name	Country	State	Location	Recorded by	Year Collected
CASC		*Tachardiella cornuta*	Mexico			Bob Zuparko	
CASC		*Tachardiella cornuta*	USA	NM		Bob Zuparko	
CSCA	csca_tcn 00025697	*Tachardiella cornuta*	USA	NM	Hidalgo County, Granite Gap	F. G. Andrews	1976
CSCA	csca_tcn 00025698	*Tachardiella cornuta*	USA	NM	Hidalgo County, Granite Gap	F. G. Andrews	1976
CSCA	csca_tcn 00025699	*Tachardiella cornuta*	USA	NM	Hidalgo County, Granite Gap	F. G. Andrews	1976
CSCA	csca_tcn 00025700	*Tachardiella cornuta*	USA	NM	Hidalgo County, Granite Gap	F. G. Andrews	1976
CSCA	csca_tcn 00025701	*Tachardiella cornuta*	USA	NM	Hidalgo County, Granite Gap	F. G. Andrews	1976
CSCA	csca_tcn 00025702	*Tachardiella cornuta*	USA	NM	Hidalgo County, Granite Gap	F. G. Andrews	1976
NHMUK	NHMUK014244047	*Tachardiella cornuta*	USA				
NHMUK	NHMUK014244048	*Tachardiella cornuta*	USA				
NHMUK	NHMUK14907346	*Tachardiella cornuta*					
NHMUK	NHMUK14907347	*Tachardiella cornuta*					
NMSU		*Tachardiella cornuta*	USA	TX	Presidio		
NMSU	23776	*Tachardiella cornuta*	USA	TX	Presidio		
USNM		*Tachardiella cornuta*	USA	NM	Little Mountain	E. Wooton	

NHMUK	NHMUK014244049	*Tachardiella ferrisi*	USA				
NHMUK	NHMUK14907348	*Tachardiella ferrisi*					
CASC		*Tachardiella fulgens*	Mexico	Sonora		Bob Zuparko	
NHMUK	NHMUK014244051	*Tachardiella fulgens*	USA				
NHMUK	NHMUK014244050	*Tachardiella fulgens*	USA				
NHMUK	NHMUK014244053	*Tachardiella fulgens*					
NHMUK	NHMUK014244052	*Tachardiella fulgens*	Mexico				
NHMUK	NHMUK14907351	*Tachardiella fulgens*					
NHMUK	NHMUK14907350	*Tachardiella fulgens*					
NHMUK	NHMUK14907352	*Tachardiella fulgens*					
NHMUK	NHMUK14907349	*Tachardiella fulgens*					
UA Ento		*Tachardiella fulgens*	USA	AZ	SABL, SCAT		
USNM		*Tachardiella fulgens*	USA	AZ	Arizona	J. Toumey	
CASC		*Tachardiella glomerella*	Mexico	Mex (NA) unknown State		Bob Zuparko	
CSCA	csca_tcn00025703	*Tachardiella glomerella*	USA	NV	Nye County, Warm Springs	C.R. Nelson	1995
CSCA	csca_tcn00025704	*Tachardiella glomerella*	USA	NV	Nye County, Warm Springs	C.R. Nelson	1995
CSCA	csca_tcn00025705	*Tachardiella glomerella*	USA	CA	San Diego County, Jamul	Gionfriddo and Gordon	1976

CSCA	csca_tcn 00025706	*Tachardiella glomerella*	USA	CA	San Bernardino County, Tecopa	Paddock et al.	1972
CSCA	csca_tcn 00025707	*Tachardiella glomerella*	USA	CA	Riverside County, Dawson Canyon	E. Reeves and R. Gill	1973
CSCA	csca_tcn 00025708	*Tachardiella glomerella*	USA	CA	Riverside County, Dawson Canyon	E. Reeves and R. Gill	1973
CSCA	csca_tcn 00025709	*Tachardiella glomerella*	USA	CA	Riverside County, Dawson Canyon	G. Reese	1973
CSCA	csca_tcn 00025710	*Tachardiella glomerella*	USA	CA	Riverside County, Dawson Canyon	E. Reeves and R. Gill	1973
CSCA	csca_tcn 00025711	*Tachardiella glomerella*	USA	CA	San Diego County, Boulevard	G. Reese	1971
CSCA	csca_tcn 00025712	*Tachardiella glomerella*	USA	CA	San Diego County, Boulevard	G. Reese	1971
CSCA	csca_tcn 00025713	*Tachardiella glomerella*	USA	CA	San Diego County, Boulevard	G. Reese	1971
CSCA	csca_tcn 00028815	*Tachardiella glomerella*	USA	NV	Clark County, Warm Springs Natural area lands recreational facility	C. R. Nelson, R. W. Baumann, W. Mathis and R. Houseman	1995
NHMUK	NHMUK014244055	*Tachardiella glomerella*	USA				
USNM		*Tachardiella glomerella*	USA	NM	Mesa; Mesilla Valley	D. Griffeths	
CASC		*Tachardiella larreae*	USA	AZ		Bob Zuparko	
CASC		*Tachardiella larreae*	USA			Bob Zuparko	

CASC		*Tachardiella larreae*	USA	CA	Imperial County	Bob Zuparko	
CASENT	8201104	*Tachardiella larreae*	USA	CA	Imperial County	E. O. Essig	1923
CASENT	8201103	*Tachardiella larreae*	USA	CA	Imperial County	E. O. Essig	1923
CASENT	8201102	*Tachardiella larreae*	USA	CA	Imperial County	E. O. Essig	1923
CASENT	8201101	*Tachardiella larreae*	USA	CA	Imperial County	E. O. Essig	1923
CASENT	8201100	*Tachardiella larreae*	USA	CA	Imperial County	E. O. Essig	1923
CSCA	csca_tcn 00025720	*Tachardiella larreae*		CA	Needles	G. Beevor and W. Cronk	1959
CSCA	csca_tcn 00025714	*Tachardiella larreae*	USA	CA	Imperial County, Algodones Dunes	L.S. Kimsey	2013
CSCA	csca_tcn 00025715	*Tachardiella larreae*	USA	CA	Imperial County, Holtville	R.J. Gill	1972
CSCA	csca_tcn 00025716	*Tachardiella larreae*	USA	CA	Imperial County, Holtville	R.J. Gill	1972
CSCA	csca_tcn 00025717	*Tachardiella larreae*	USA	CA	Imperial County, Holtville	R.J. Gill	1972
CSCA	csca_tcn 00025718	*Tachardiella larreae*	USA	CA	Imperial County, Holtville	R.J. Gill	1972
CSCA	csca_tcn 00025719	*Tachardiella larreae*	USA	CA	Imperial County, Holtville	R.J. Gill	1972
CSCA	csca_tcn 00028814	*Tachardiella larreae*	USA	CA	Imperial County, Holtville	R.J. Gill	1972
MSU	msuc_arc_ 112920	*Tachardiella larreae*					
NHMUK	NHMUK0 14244056	*Tachardiella larreae*	USA				
NHMUK	NHMUK0 14244057	*Tachardiella larreae*	USA				
NHMUK	NHMUK0 14244060	*Tachardiella larreae*					

NHMUK	NHMUK14907355	*Tachardiella larreae*					
NHMUK	NHMUK14907357	*Tachardiella larreae*					
NHMUK	NHMUK14907353	*Tachardiella larreae*					
NHMUK	NHMUK14907356	*Tachardiella larreae*					
NHMUK	NHMUK14907354	*Tachardiella larreae*					
UA Ento		*Tachardiella larreae*	USA	AZ	La Paz County	Werner Olson	1989
UA Ento		*Tachardiella larreae*	USA, MX	AZ	PIML, YUMA		
USNM		*Tachardiella larreae*	USA	AZ	Arizona		1881
		Tachardiella larreae	Mexico				
CASC		*Tachardiella mexicana*	Mexico	Mex unknown		Bob Zuparko	
CASC		*Tachardiella mexicana*	Mexico	Sonora		Bob Zuparko	
CASC		*Tachardiella mexicana*	Mexico	Oaxaca		Bob Zuparko	
CASC		*Tachardiella mexicana*	USA	CA	Inyo County	Bob Zuparko	
MCZ		*Tachardiella mexicana*	Mexico	Coahuila	near Frontera	Townsend	
MCZ		*Tachardiella mexicana*	Mexico	Coahuila	near Frontera	Townsend	
MCZ		*Tachardiella mexicana*					

MSU	msuc_arc_112921	*Tachardiella mexicana*					
NHMUK	NHMUK014244061	*Tachardiella mexicana*	USA				
NHMUK	NHMUK14907359	*Tachardiella mexicana*					
NHMUK	NHMUK14907358	*Tachardiella mexicana*					
USNM		*Tachardiella mexicana*	Mexico	Tabasco	Near Frontera	C. Townsend	1897
CSCA	csca_tcn00025721	*Tachardiella pustulata*	USA	CA	San Bernardino County, Tecopa	E.L. Paddock	1972
CSCA	csca_tcn00025722	*Tachardiella pustulata*	USA	CA	San Bernardino County, Tecopa	Paddock et al.	1972
CSCA	csca_tcn00025723	*Tachardiella pustulata*	USA	CA	San Bernardino County, Tecopa	Paddock et al.	1972
CSCA	csca_tcn00025724	*Tachardiella pustulata*	USA	CA	Riverside County, Temecula	B. Reed	1965
CSCA	csca_tcn00025725	*Tachardiella pustulata*	USA	CA	Imperial County, Calexico	R. Waegner	1965
NHMUK	NHMUK14907362	*Tachardiella pustulata*					
USNM		*Tachardiella pustulata*	USA	AZ	Arizona	J. Toumey	
NHMUK	NHMUK014244065	*Tachardiella pustulata*	USA				
CASC		*Tachardiella spp.*	Mexico	Morelos		Bob Zuparko	
NHMUK	NHMUK014244054	*Tachardiella spp.*	USA				
NHMUK	NHMUK014244059	*Tachardiella spp.*	USA				
NHMUK	NHMUK014244058	*Tachardiella spp.*	USA				

Acronym	Institution
ASUH	Arizona State University Vascular Plant Herbarium
CASC	California Academy of Sciences
CDFA	California Department of Food and Agriculture
CSCA	California State Collection of Arthropods
DES	Desert Botanical Garden Herbarium
FMNH	Field Museum of Natural History
GBIF	Global Biodiversity Information Facility
iDigBio	Integrated Digitized Biocollections
iNaturalist	Web based community only, documented human observations of specimens only
MCZ	Museum of Comparative Zoology, Harvard University
MSU	Michigan State University Entomology
NHMUK	Natural History Museum UK
NMSU	New Mexico State University Arthropod Collection
RSA	Rancho Santa Ana Botanic Garden, Pomona College
SCAN	Symbiota Collections of Arthropods Networks
SDNH	San Diego Natural History Museum
UAH	University of Arizona Herbarium
UCBMH	University of Colorado Boulder Natural History Museum Herbarium
USNM	National Museum of Natural History, Smithsonian (Formerly the USNM)

APPENDIX B

Recorded Field Observations of *Tachardiella* spp. – iNaturalist.org

ID #	Scientific name	Location	County	Date observed	URL
107188311	*Tachardiella ferrisi*	Riverside County, CA, USA	Riverside	2022-02-20	https://www.inaturalist.org/observations/107188311
107361396	*Tachardiella ferrisi*	Riverside County, CA, USA	Riverside	2022-02-20	https://www.inaturalist.org/observations/107361396
60546200	*Tachardiella fulgens*	Saguaro National Park, Pima County, US-AZ, US	Pima	2020-09-23	https://www.inaturalist.org/observations/60546200
69019724	*Tachardiella fulgens*	Coronado National Forest, Tucson, AZ, US	Pima	2021-02-03	https://www.inaturalist.org/observations/69019724
2805961	*Tachardiella fulgens*	Arizona, United States	Pima	2016-02-24	http://www.inaturalist.org/observations/2805961
2805963	*Tachardiella fulgens*	Arizona, United States	Pima	2016-02-24	http://www.inaturalist.org/observations/2805963
29960033	*Tachardiella fulgens*	Pima County, AZ, USA	Pima	2019-07-31	https://www.inaturalist.org/observations/29960033
36174338	*Tachardiella fulgens*	Sabino Canyon, Catalina Foothills, AZ 85750, USA	Pima	2013-03-02	https://www.inaturalist.org/observations/36174338
63370918	*Tachardiella fulgens*	Tucson, AZ 85748, USA	Pima	2019-02-02	https://www.inaturalist.org/observations/63370918
105512735	*Tachardiella fulgens*	Pima County, AZ, USA	Pima	2022-01-08	https://www.inaturalist.org/observations/105512735
8047923	*Tachardiella fulgens*	Guaymas, Sonora, Mexico	Guaymas	2017-09-09	https://www.inaturalist.org/observations/8047923
13763287	*Tachardiella larreae*	E US Highway 70, Safford, AZ, US	Graham	2018-06-22	https://www.inaturalist.org/observations/13763287

13763594	*Tachardiella larreae*	E US Highway 70, Safford, AZ, US	Graham	2018-06-22	https://www.inaturalist.org/observations/13763594
15033710	*Tachardiella larreae*	Elvira, Tucson, AZ, USA	Pima	2018-08-01	https://www.inaturalist.org/observations/15033710
19501584	*Tachardiella larreae*	Pima County, US-AZ, US	Pima	2019-01-07	https://www.inaturalist.org/observations/19501584
38317205	*Tachardiella larreae*	San Simon, AZ, US	Cochise	2020-02-03	https://www.inaturalist.org/observations/38317205
38318210	*Tachardiella larreae*	N Cavot Rd, San Simon, AZ, US	Cochise	2020-02-03	https://www.inaturalist.org/observations/38318210
38318497	*Tachardiella larreae*	N Cavot Rd, San Simon, AZ, US	Cochise	2020-02-03	https://www.inaturalist.org/observations/38318497
38318556	*Tachardiella larreae*	N Cavot Rd, San Simon, AZ, US	Cochise	2020-02-03	https://www.inaturalist.org/observations/38318556
38319638	*Tachardiella larreae*	N Cavot Rd, San Simon, AZ, US	Cochise	2020-02-03	https://www.inaturalist.org/observations/38319638
39496085	*Tachardiella larreae*	Sahuarita, AZ, US	Pima	2020-02-29	https://www.inaturalist.org/observations/39496085
71758492	*Tachardiella larreae*	Parker, AZ, US	La Paz	2021-03-21	https://www.inaturalist.org/observations/71758492
72033671	*Tachardiella larreae*	Tucson, AZ, USA	Pima	2021-03-25	https://www.inaturalist.org/observations/72033671
95211571	*Tachardiella larreae*	Maricopa, Arizona, United States	Maricopa	2021-09-06	https://www.inaturalist.org/observations/95211571
102274727	*Tachardiella larreae*	US-93, Kirkland, AZ, US	Yavapai	2021-11-27	https://www.inaturalist.org/observations/102274727
102281678	*Tachardiella larreae*	Kirkland, AZ, US	Yavapai	2021-11-27	https://www.inaturalist.org/observations/102281678

102296744	*Tachardiella larreae*	Kirkland, AZ, US	Yavapai	2021-11-27	https://www.inaturalist.org/observations/102296744
104731373	*Tachardiella larreae*	Old Wikieup Hillside Rd, Wikieup, AZ, US	Mohave	2021-11-23	https://www.inaturalist.org/observations/104731373
104731466	*Tachardiella larreae*	Old Wikieup Hillside Rd, Wikieup, AZ, US	Mohave	2021-11-23	https://www.inaturalist.org/observations/104731466
105755289	*Tachardiella larreae*	Yuma Proving Ground, Ehrenberg, AZ, US	La Paz	2022-01-28	https://www.inaturalist.org/observations/105755289
106449368	*Tachardiella larreae*	Cavot Rd, San Simon, AZ, US	Cochise	2022-02-08	https://www.inaturalist.org/observations/106449368
108095873	*Tachardiella larreae*	Sahuarita, AZ 85629, USA	Pima	2022-03-04	https://www.inaturalist.org/observations/108095873
111351042	*Tachardiella larreae*	Willow Beach, AZ, US	Mohave	2022-04-09	https://www.inaturalist.org/observations/111351042
112017378	*Tachardiella larreae*	Sahuarita, AZ, US	Pima	2022-04-18	https://www.inaturalist.org/observations/112017378
113591048	*Tachardiella larreae*	Amboy, CA, US	San Bernardino	2022-04-28	https://www.inaturalist.org/observations/113591048
8437383	*Tachardiella larreae*	Mojave National Preserve, Baker, CA, US	San Bernardino	2017-10-15	https://www.inaturalist.org/observations/8437383
14956534	*Tachardiella larreae*	Imperial County, US-CA, US	Imperial	2018-07-17	https://www.inaturalist.org/observations/14956534
17806695	*Tachardiella larreae*	Mojave National Preserve, Essex, CA, US	San Bernardino	2018-10-21	https://www.inaturalist.org/observations/17806695
19734513	*Tachardiella larreae*	Mojave National Preserve, San Bernardino County, US-CA, US	San Bernardino	2019-01-19	https://www.inaturalist.org/observations/19734513
36866598	*Tachardiella larreae*	Indio, CA, US	Riverside	2019-12-22	https://www.inaturalist.org/observations/36866598

40440348	*Tachardiella larreae*	Imperial County, CA, USA	Imperial	2020-02-29	https://www.inaturalist.org/observations/40440348
65306000	*Tachardiella larreae*	Joshua Tree National Park, Desert Hot Springs, CA, US	Riverside	2020-11-20	https://www.inaturalist.org/observations/65306000
65306119	*Tachardiella larreae*	Joshua Tree National Park, Desert Hot Springs, CA, US	Riverside	2020-11-20	https://www.inaturalist.org/observations/65306119
65306176	*Tachardiella larreae*	Joshua Tree National Park, Desert Hot Springs, CA, US	Riverside	2020-11-20	https://www.inaturalist.org/observations/65306176
65602686	*Tachardiella larreae*	Indio, CA, US	Riverside	2020-11-23	https://www.inaturalist.org/observations/65602686
66721695	*Tachardiella larreae*	Ludlow, CA 92338, USA	San Bernardino	2020-12-16	https://www.inaturalist.org/observations/66721695
71230054	*Tachardiella larreae*	Indio, CA, US	Riverside	2021-03-14	https://www.inaturalist.org/observations/71230054
71230240	*Tachardiella larreae*	Indio, CA, US	Riverside	2021-03-14	https://www.inaturalist.org/observations/71230240
71230441	*Tachardiella larreae*	Indio, CA, US	Riverside	2021-03-14	https://www.inaturalist.org/observations/71230441
71230720	*Tachardiella larreae*	Indio, CA, US	Riverside	2021-03-14	https://www.inaturalist.org/observations/71230720
71230889	*Tachardiella larreae*	Indio, CA, US	Riverside	2021-03-14	https://www.inaturalist.org/observations/71230889
71230997	*Tachardiella larreae*	Indio, CA, US	Riverside	2021-03-14	https://www.inaturalist.org/observations/71230997
71231155	*Tachardiella larreae*	Indio, CA, US	Riverside	2021-03-14	https://www.inaturalist.org/observations/71231155
71231552	*Tachardiella larreae*	Indio, CA, US	Riverside	2021-03-14	https://www.inaturalist.org/observations/71231552

71231770	*Tachardiella larreae*	Indio, CA, US	Riverside	2021-03-14	https://www.inaturalist.org/observations/71231770
74961639	*Tachardiella larreae*	Joshua Tree, CA 92252, USA	San Bernardino	2021-04-19	https://www.inaturalist.org/observations/74961639
75102877	*Tachardiella larreae*	San Bernardino County, CA, USA	San Bernardino	2021-04-24	https://www.inaturalist.org/observations/75102877
79242909	*Tachardiella larreae*	Mojave National Preserve, Essex, CA, US	San Bernardino	2021-05-17	https://www.inaturalist.org/observations/79242909
91751501	*Tachardiella larreae*	Winters Rd, Yucca Valley, CA, US	San Bernardino	2021-08-19	https://www.inaturalist.org/observations/91751501
93353666	*Tachardiella larreae*	Joshua Tree National Park, Desert Hot Springs, CA, US	Riverside	2021-09-01	https://www.inaturalist.org/observations/93353666
93353780	*Tachardiella larreae*	Joshua Tree National Park, Desert Hot Springs, CA, US	Riverside	2021-09-01	https://www.inaturalist.org/observations/93353780
97478893	*Tachardiella larreae*	San Bernardino County, CA, USA	San Bernardino	2021-09-25	https://www.inaturalist.org/observations/97478893
97840244	*Tachardiella larreae*	Joshua Tree National Park, Desert Hot Springs, CA, US	Riverside	2021-10-10	https://www.inaturalist.org/observations/97840244
97840380	*Tachardiella larreae*	Joshua Tree National Park, Desert Hot Springs, CA, US	Riverside	2021-10-10	https://www.inaturalist.org/observations/97840380
97841290	*Tachardiella larreae*	Joshua Tree National Park, Desert Hot Springs, CA, US	Riverside	2021-10-10	https://www.inaturalist.org/observations/97841290
98808792	*Tachardiella larreae*	Joshua Tree, CA, US	San Bernardino	2021-10-20	https://www.inaturalist.org/observations/98808792
99348947	*Tachardiella larreae*	Joshua Tree National Park, Desert Hot Springs, CA, US	Riverside	2021-10-24	https://www.inaturalist.org/observations/99348947
99349424	*Tachardiella larreae*	Joshua Tree National Park, Desert Hot Springs, CA, US	Riverside	2021-10-24	https://www.inaturalist.org/observations/99349424

99349823	*Tachardiella larreae*	Joshua Tree National Park, Desert Hot Springs, CA, US	Riverside	2021-10-24	https://www.inaturalist.org/observations/99349823
99350477	*Tachardiella larreae*	Joshua Tree National Park, Desert Hot Springs, CA, US	Riverside	2021-10-24	https://www.inaturalist.org/observations/99350477
99351004	*Tachardiella larreae*	Joshua Tree National Park, Desert Hot Springs, CA, US	Riverside	2021-10-24	https://www.inaturalist.org/observations/99351004
103419540	*Tachardiella larreae*	Death Valley National Park, Independence, CA, US	Inyo	2021-12-10	https://www.inaturalist.org/observations/103419540
105686350	*Tachardiella larreae*	Indio, CA, US	Riverside	2022-01-27	https://www.inaturalist.org/observations/105686350
107179857	*Tachardiella larreae*	Joshua Tree National Park, Desert Hot Springs, CA, US	Riverside	2022-02-20	https://www.inaturalist.org/observations/107179857
107179923	*Tachardiella larreae*	Joshua Tree National Park, Desert Hot Springs, CA, US	Riverside	2022-02-20	https://www.inaturalist.org/observations/107179923
107180037	*Tachardiella larreae*	Joshua Tree National Park, Desert Hot Springs, CA, US	Riverside	2022-02-20	https://www.inaturalist.org/observations/107180037
107180477	*Tachardiella larreae*	Joshua Tree National Park, Desert Hot Springs, CA, US	Riverside	2022-02-20	https://www.inaturalist.org/observations/107180477
107180824	*Tachardiella larreae*	Joshua Tree National Park, Desert Hot Springs, CA, US	Riverside	2022-02-20	https://www.inaturalist.org/observations/107180824
107327219	*Tachardiella larreae*	Riverside, California, United States	Riverside	2022-02-20	https://www.inaturalist.org/observations/107327219
107620237	*Tachardiella larreae*	San Diego County, US-CA, US	San Diego	2022-02-25	https://www.inaturalist.org/observations/107620237
108989499	*Tachardiella larreae*	Black Eagle Mine Road	Riverside	2022-03-14	https://www.inaturalist.org/observations/108989499
114873433	*Tachardiella larreae*	Joshua Tree National Park, Desert Hot Springs, CA, US	Riverside	2022-05-01	https://www.inaturalist.org/observations/114873433

114873922	*Tachardiella larreae*	Joshua Tree National Park, Desert Hot Springs, CA, US	Riverside	2022-05-01	https://www.inaturalist.org/observations/114873922
116586365	*Tachardiella larreae*	Mesquite, NV, US	Clark	2022-05-03	https://www.inaturalist.org/observations/116586365
110839277	*Tachardiella larreae*	Henderson, NV, US	Clark	2022-04-08	https://www.inaturalist.org/observations/110839277
111405313	*Tachardiella larreae*	Henderson, NV, US	Clark	2022-04-08	https://www.inaturalist.org/observations/111405313
112391859	*Tachardiella larreae*	Henderson, NV, US	Clark	2022-04-06	https://www.inaturalist.org/observations/112391859
114579181	*Tachardiella larreae*	S Bozzolo St, Las Vegas, NV, US	Clark	2022-03-02	https://www.inaturalist.org/observations/114579181
119768967	*Tachardiella larreae*	Grant County, NM, USA	Grant	2022-04-11	https://www.inaturalist.org/observations/119768967
12302741	*Tachardiella larreae*	NM-9, Silver City, NM, US	Grant	2018-05-08	https://www.inaturalist.org/observations/12302741
12302821	*Tachardiella larreae*	NM-9, Silver City, NM, US	Grant	2018-05-08	https://www.inaturalist.org/observations/12302821
12310378	*Tachardiella larreae*	W Altura Ave, Deming, NM, US	Luna	2018-05-08	https://www.inaturalist.org/observations/12310378
12310460	*Tachardiella larreae*	W Altura Ave, Deming, NM, US	Luna	2018-05-08	https://www.inaturalist.org/observations/12310460
12466674	*Tachardiella larreae*	N Lincoln St, Columbus, NM, US	Luna	2018-05-08	https://www.inaturalist.org/observations/12466674
12466697	*Tachardiella larreae*	W Altura Ave, Deming, NM, US	Luna	2018-05-08	https://www.inaturalist.org/observations/12466697
12466859	*Tachardiella larreae*	19724,Äì19858 N Highway 11, Deming, NM, US	Luna	2018-05-08	https://www.inaturalist.org/observations/12466859

12466876	*Tachardiella larreae*	607 W Altura Ave, Columbus, NM, US	Luna	2018-05-08	https://www.inaturalist.org/observations/12466876
12467588	*Tachardiella larreae*	McCall, Deming, NM, US	Luna	2018-05-08	https://www.inaturalist.org/observations/12467588
38315604	*Tachardiella larreae*	Animas, NM, US	Hidalgo	2020-02-03	https://www.inaturalist.org/observations/38315604
38316292	*Tachardiella larreae*	Lordsburg, NM, US	Hidalgo	2020-02-03	https://www.inaturalist.org/observations/38316292
38316424	*Tachardiella larreae*	Lordsburg, NM, US	Hidalgo	2020-02-03	https://www.inaturalist.org/observations/38316424
51714861	*Tachardiella larreae*	NM-9, Silver City, NM, US	Grant	2020-07-01	https://www.inaturalist.org/observations/51714861
51714904	*Tachardiella larreae*	NM-9, Silver City, NM, US	Grant	2020-07-01	https://www.inaturalist.org/observations/51714904
66862921	*Tachardiella larreae*	Hidalgo County, NM, USA	Hidalgo	2019-09-06	https://www.inaturalist.org/observations/66862921
70520865	*Tachardiella larreae*	Desert Star Rd, Las Cruces, NM, US	Doña Ana	2021-03-03	https://www.inaturalist.org/observations/70520865
98882070	*Tachardiella larreae*	Lordsburg, NM, US	Hidalgo	2021-10-20	https://www.inaturalist.org/observations/98882070
109954267	*Tachardiella larreae*	Lincoln National Forest, La Luz, NM, US	Otero	2022-03-30	https://www.inaturalist.org/observations/109954267
110144827	*Tachardiella larreae*	Las Cruces, NM, USA	Doña Ana	2022-04-01	https://www.inaturalist.org/observations/110144827
38890865	*Tachardiella larreae*	Scenic Dr, El Paso, TX, US	El Paso	2020-02-19	https://www.inaturalist.org/observations/38890865
118818584	*Tachardiella larreae*	The University of Texas at El Paso, El Paso, TX, US	El Paso	2022-05-26	https://www.inaturalist.org/observations/118818584

109156092	*Tachardiella larreae*	West Central El Paso, El Paso, TX 79902, USA	El Paso	2022-03-19	https://www.inaturalist.org/observations/109156092
109493560	*Tachardiella larreae*	The University of Texas at El Paso, El Paso, TX, US	El Paso	2022-03-25	https://www.inaturalist.org/observations/109493560
91908833	*Tachardiella larreae*	Not listed, private		2021-06-10	https://www.inaturalist.org/observations/91908833

Observations by M. Pool and colleagues

ID	Lat	Lon	Elevation (m)	Date observed	Location	Notes
1	33.22738096	-112.765934	138.240875	2018-03-05	Gila Dam Bridge	Arrowweed only, no lac
2	33.22652299	-112.766882	170.855026	2018-03-04	Gila River	Arrowweed only, no lac
3	32.320122	-110.810272	858.38	2019-03-16	Sabino Canyon, Pima Co., AZ	T. fulgens on C. glandulosa, dense
4	32.25156901	-111.164487	902.087769	2018-03-08	Kings Canyon, Pima Co., AZ	Kings Canyon T. fulgens on C. glandulosa
5	32.25250502	-111.163702	906.934265	2018-03-08	Kings Canyon, Pima Co., AZ	Kings Canyon T. fulgens on C. glandulosa
6	32.25253603	-111.163692	907.942566	2018-03-08	Kings Canyon, Pima Co., AZ	Kings Canyon T. fulgens on C. glandulosa
7	32.25144999	-111.164606	901.631897	2018-03-08	Kings Canyon, Pima Co., AZ	Kings Canyon T. fulgens on C. glandulosa
8	32.25079704	-111.165382	856.330872	2018-03-08	Kings Canyon, Pima Co., AZ	Kings Canyon T. fulgens on C. glandulosa
9	32.72498201	-113.117649	854.748108	2018-03-08	Lago Seco, AZ	Larrea tridentata only. Sample of T. larreae found by tour guide
10	36.9615222	-117.375	N/A	2016-04	Death Valley, CA	Larrea tridentata with T. larreae. Found by Chris White on camping trip.
11	32.33936	-112.84792	548.64	2021-02-22	Darby Well Rd., Ajo	Tachardiella larreae on Larrea tridentata, first reported by Instagram user Vikki Jackson
12	32.339505	-112.849128	548.64	2022-10-17	Bates Well Rd., Ajo	Tachardiella larreae on Larrea tridentata, found across from dinner site of Sonoran

						Conference in Ajo 2017
13	32.143987	-110.98997	N/A	2022	Valencia Site	Larrea tridentata seen by Allen Denoyer in several spots on site
14	32.226449	-109.047089	N/A	2022	AZ/NM border	Larrea tridentata found in abundance by Allen Denoyer near border signs off exit there from I-10. N. Cavot Rd to Chato Rd.

APPENDIX C

Herbaria specimens found with *Tachardiella* spp.

Institution	Associated Lac Insect	Catalog Number	Description	Herbarium specimen	Collector	Date collected	Country	State/ Province	Associated References
ASUH	*Tachardiella fulgens*	ASU0019885	Two branches of C. glandulosa, one with thick encrustations of T. fulgens	*Coursetia glandulosa*	L. McGill	3/30/1970	Mexico	Sonora	
DES	*Tachardiella fulgens*	DES00003562	Two stems of C. glandulosa with several dense encrustations of T. fulgens	*Coursetia glandulosa*	Donald J. Pinkava	3/30/1970	Mexico	Sonora	
FMNH	*Tachardiella fulgens*	275051	Three stems of C. glandulosa, one broken, encrusted with T. fulgens	*Coursetia glandulosa*	Edward Palmer	11/30/1896	Mexico	Colima	
FMNH	*Tachardiella fulgens*	275050	One stem of C. glandulosa and a pile of crushed T. fulgens lac. Label text: A gum exuded by the stems and branches of a Mexican shrub. The gum is largely collected by the natives and used by them in sweetened water, as a remedy for fever and consumption. Sonora (1897) Mexico	*Coursetia glandulosa*	Edward Palmer	11/30/1896	Mexico	San Luis Potosi	

NMNH	*Tachardiella pustulata*	93283	Botanical specimen of Pluchea sericea with top stem infested with T. pustulata	*Pluchea sericea*	E. Palmer and later R. Bye	12/21/1884 to 1/1/1885	Mexico	Sonora	Bye 1979: 135-162.
NMNH	*Tachardiella fulgens*	24885	Botanical specimen of Coursetia glandulosa with separate stem covered with Tachardiella fulgens	*Coursetia glandulosa*		3/25/1890 - 4/8/1890	Mexico	Sonora	McVaugh 1956:319
NMNH	*Clavaspis coursetiae*	24884	Botanical specimen of Coursetia glandulosa with separate stem covered with Clavaspis coursetiae (pidgeon plum scale)	*Coursetia glandulosa*	R. Bye & J. Whitacre	1887	Mexico	Sonora	McVaugh 1956:219-220
NMNH	*Tachardiella larreae*	14235	Botanical specimen of Larrea tridentata infested with Tachardiella larreae	*Larrea tridentata*	Edward Palmer	1875			McVaugh 1956: 66-67
RSA	*Tachardiella fulgens*	RSA0206756	Large bent branch encrusted with T. fulgens. "Specimen with Tachardiella lac"	*Coursetia glandulosa*		9/23/44	United States	Arizona	
SDNH	*Tachardiella larreae*	SD00042043	One branch of L. tridentata with a single encrustation of T. larreae on one stem. "Lac (scale insect) attached (= shegoi ushap, River Pima).	*Larrea tridentata*	Amadeo Rea	3/28/1986	United States	Arizona	

UAH	*Tachardiella fulgens*	10354	A full stem of C. glandulosa bent over onto page. Stem covered entirely with T. fulgens. "This species frequently produces lac, sometimes rather abundantly"	*Coursetia glandulosa*	R. H. Peebles	9/27/34	United States	Arizona	
UAH	*Tachardiella larreae*	168208	Two stems of Larrea tridentata. The larger has encrustation of T. larreae in sections. "Dominant 5 foot shrub with lac on branches"	*Larrea tridentata*	Vorsila L. Bohrer	4/23/1965	United States	Arizona	
UAH	*Tachardiella larreae*	365178	Six stems of Larrea divaricata with multiple encrustations of T. larrea on all of them. "Dominant shrub; several with extensive encrustations of orange lac"	*Larrea divaricata subsp. tridentata*	R. S. Felger	3/12/2003	United States	Arizona	
UAH	*Tachardiella pustulata*	298912	Three stems of Pluchea sericea, two with T. pustulata on some of the branches. "Fairly common along margin of riverbed; shrubs 1.5-2+m tall; this one with Orange red lac."	*Pluchea sericea*	R. S. Felger	10/25/1992	Mexico	Sonora	
UCBMH	*Tachardiella fulgens*	1578368	One large stem of C. glandulosa with several small encrustations of T. fulgens. "scattered trees (small) in short tree forest near small arroyos; orange lac (said to be made by ants according to Tarahumara, actually a	*Coursetia glandulosa*	Robert A. Bye	10/3/72	Mexico	Chihuahua	

			scale insect) is prized as a remedy for stomach aches and hangovers; mix with chili and water; beat medicine; Used as an adhesive also; “samo; ari; gomilla; goma”						
UCBMH	*Tachardiella fulgens*	1578566	Two stems of C. glandulosa with several encrustations of T. fulgens. "small tree ca. 3 m high; with orange scale insects (Llaveia axin) and deposits (called “ari” used medicinally) which are tended by ants (ants collected); Tarahumara name: samo"	*Coursetia glandulosa*	Robert A. Bye	7/30/77	Mexico	Chihuahua	

Acronym	Institution
ASUH	Arizona State University Vascular Plant Herbarium
CASC	California Academy of Sciences
CDFA	California Department of Food and Agriculture
CSCA	California State Collection of Arthropods
DES	Desert Botanical Garden Herbarium
FMNH	Field Museum of Natural History
GBIF	Global Biodiversity Information Facility
iDigBio	Integrated Digitized Biocollections
iNaturalist	Web based community only, documented human observations of specimens only
MCZ	Museum of Comparative Zoology, Harvard University
MSU	Michigan State University Entomology
NHMUK	Natural History Museum UK
NMSU	New Mexico State University Arthropod Collection
RSA	Rancho Santa Ana Botanic Garden, Pomona College
SCAN	Symbiota Collections of Arthropods Networks
SDNH	San Diego Natural History Museum
UAH	University of Arizona Herbarium
UCBMH	University of Colorado Boulder Natural History Museum Herbarium
USNM	National Museum of Natural History, Smithsonian (Formerly the USNM)

APPENDIX D

Biological specimens cataloged with Anthropological Collections

Institution	Catalog #	Object Name	Collector	Associated Culture	Object Materials	Earliest Date	Geographic Location	References
AMNH	50.1/ 5243	Gum, handle making	Kissell	Papago (Tohono O'odham)	Wood, gum (insect lac on stem); *Tachardiella fulgens* on *Coursetia glandulosa*	1911 CE collected	Santa Rosa, Tohono O'odham Nation, Pima Co., AZ	Kissell 1916: 203-206
AMNH	50.1/ 4646	Gum, pot mending	Lumholtz	Papago (Tohono O'odham)	Wood (greasewood) gum, plant fiber (insect lac on stem); *Tachardiella larreae* on *Larrea tridentata*	1911 CE collected	Arizona	Lumholtz 1912: 223
ASM	A-8843-x	Stick lac	Haury	Hohokam/Tohono O'odham	*Tachardiella larreae on Larrea tridentata*		Castle Mountains, AZ	Haury 1950 Pl. 19 a-h
ASM	A-8847	Lac, raw material	Haury	Hohokam/Tohono O'odham	*Tachardiella larreae*		Castle Mountains, AZ	Haury 1950: 443
ASM	B-89	Stick lac	Haury	Hohokam/Tohono O'odham	*Tachardiella larreae on Larrea tridentata*		Castle Mountains, AZ	Haury 1950: 161-169
ASM	A-3710	Stick with resin	Haury?	Tohono O'odham	*Tachardiella larreae on Larrea tridentata*		Santa Rosa Wash, Pima County, AZ	

ASM	E-3640-A	Lac for mending pottery	Ignacio	Tohono O'odham	*Tachardiella larreae on Larrea tridentata*	1958 CE	Tohono O'odham Indian Reservation, Sells District, Pima Co. AZ	
ASM	E-8819	Glue	Manson	Seri (Comcáac)	Insect lac, *Tachardiella larreae*	1930 CE	Sonora, Mexico	
ASM	2019-183-6	Stick lac (Tachardiella larreae)	Moser	Seri (Comcáac)	*Tachardiella larreae* on *Larrea tridentata*		Desemboque, (area) Sonora, Mexico	Felger and Moser 1985: 386, fig. 17.6
NMAI	11/6875	Gum/Pitch/Resin	Davis	Chemehuevi	Insect Lac; *Tachardiella larreae*	1922 CE collected	Chemehuevi Valley; San Bernardino County; CA	
NMAI	10/2730	Gum/Pitch/Resin	Davis	Mohave (Mojave)	Insect Lac; *Tachardiella larreae*	1920 CE collected	Needles; San Bernardino County; CA	
NMAI	8/9830	Gum/Pitch/Resin	Davis	Papago (Tohono O'odham)	Insect Lac, wood; *Tachardiella larreae*	1919 CE collected	Gu Achi (Santa Rosa), Tohono O'odham Reservation; Pima County; AZ	Fontana et al. 1962: 80-81, 118.

NMAI	12/9692	Gum/Pitch/Resin	Davis	Seri (Comcáac)	Insect Lac; *Tachardiella larreae*	1924 CE collected	Isla Tiburón; Hermosillo Municipality; Sonora State; Mexico	Felger and Moser 1985: 128-130; Sheridan and Parezo 1996: 206
NMAI	11/2234	Gum/Pitch/Resin	Davis	Seri (Comcáac)	Insect Lac; *Tachardiella larreae*	1922 CE collected	Isla Tiburón; Hermosillo Municipality; Sonora State; Mexico	Felger and Moser 1985: 128-130; Sheridan and Parezo 1996: 206
NMAI	17/6551	Gum/Pitch/Resin	Davis	Yuma (Quechan)	Insect Lac; *Tachardiella pustulata* on *Pluchea sericea*	1930 CE collected	Arizona, California (at the border of, possibly?) Yuma is in Arizona.	
NMAI	13/4193	Gum/Pitch/Resin	Harrington	Northern Paiute (Paviotso)	Resin, wood (Insect Lac - possible, requires further analysis)	1924 CE collected	Stillwater, Fallon Reservation (Stillwater Reservation); Churchill County; NV	
NMAI	14/1853	Gum/Pitch/Resin	Harrington	Paiute, Southern, Moapa	Insect Lac; *Tachardiella larreae*	1925 CE collected	Moapa, Moapa River Reservation; Clark County; NV	

NMAI	24/8475	Gum/Pitch/Resin	Moser/White	Seri (Comcáac)	Resin (Insect Lac - possible, requires further analysis)	1965-1970 CE collected	Sonora, Mexico	Felger and Moser 1985: 128-130; Sheridan and Parezo 1996: 133
NMNH	E429881-0	Insect Exudate	Boudreau	Tarahumara (Rarámuri)	Zoological material, possibly insect lac - requires further analysis	Early - mid 1980s	Polanco Area, Chihuahua, Mexico	
NMNH	E165099-0	Gum cement	Coville	Panamint (Koso, Timbisha Shoshone)	Insect Lac; *Tachardiella larreae*	1892	Panamint Mountains, Inyo County, California	Coville 1892: 351-362. p. 361
NMNH	E76146-0	Gum of Arrow Weed	Palmer	Cocopah (Cucapá)	Insect lac, *Tachardiella pustulata* on *Pluchea sericea*	1885 CE collected	Arizona	McVaugh 1956: 275.
NMNH	E14338-0	Gum resin	Powell	Paiute	Insect Lac; *Tachardiella larreae*	1874 CE	Utah, South	
NMNH	E217981-0	Creosote bush gum	Russell	Pima (Akimel O'odham)	Insect lac, *Tachardiella larreae* on *Larrea tridentata*	1901 CE collected	Sacaton, Gila River Indian Reservation, Pinal County, AZ	Russell 1908: 131

NMNH	E218083-0	Gum for mending	Russell	Pima (Akimel O'odham)	Insect lac, *Tachardiella larreae*	1901 CE collected	Sacaton, Gila River Indian Reservation, Pinal County, AZ	Russell 1908: 131
PHM	1-19767	Creosote gum	Austin	Mojave?	Insect Lac; *Tachardiella larreae* on *Larrea tridentata*	c. 1900s	California, Southern	Austin 1903
PHM	3-2975	Gum, arrowweed (Pluchea sericea)	Gifford	Cocopah (Cucapá)	Insect lac on branch; *Tachardiella pustulata* on *Pluchea sericea*	1926 CE collected	Sonora or Baja California, Lower Colorado river, Cocopa, Mexico	Gifford 1933
PHM	1-10960	Gum for painting arrows	Kroeber	Chemehuevi	Gum (Insect Lac - possible, requires further analysis)	1907 CE collected	Cabazon Reservation, Riverside County, CA	
PMAE	34-24-10/3708	Gum, Creosote bush	Kelly	Southern Paiute, Chemehuevi	Insect Lac, *Tachardiella larreae*	1933	Parker, La Paz County, Arizona	Fowler and Garey-Sage 2016
PMAE	34-24-10/3709	Gum, creosote bush, paint	Kelly	Southern Paiute, Chemehuevi	Insect Lac, *Tachardiella larreae,* mineral paint	1933	Parker, La Paz County, Arizona	Fowler and Garey-Sage 2016
PMAE	76-20-10/100082	Native gum (larrea mexicana); carteria larreae deposited by scale	Palmer	Mohave (Mojave)	Insect Lac; *Tachardiella larreae*	1876 CE	North America/United States	

PMAE	76-20-10/9442	Gum of sarrea mexicana [sic]	Palmer	Paiute, Southern	Wood, insect lac; *Tachardiella larreae*	1875 CE	Utah, South	
UPENN	17356	"Aree", Food	Pepper, William	Tarahumara (Rarámuri)	Insect lac, *Tachardiella fulgens* on *Coursetia glandulosa*	1890s	Barancas (Canyons)	McVaugh 1956:68

APPENDIX E

Anthropological Artifacts containing Lac by Institution

Instit.	Catalog #	Object Name	Site Name	Culture	Object Materials	Earliest Date	Result	Geographic Location	References
AFM	2127	Jar, Pottery		Seri (Comcáac)	Ceramic, insect lac	1947 CE	Insect Lac	Desemboque, Sonora, Mexico.	
AFM	6065	Jar, Pottery		Seri (Comcáac)	Ceramic, paint, insect lac		Insect Lac		(Bowen and Moser 1968: 89-132)
AFM	6066a	Jar, Pottery		Seri (Comcáac)	Ceramic, paint, insect lac		Insect Lac		(Bowen and Moser 1968: 89-132)
AFM	6066b	Lid, Pottery		Seri (Comcáac)	Ceramic, insect lac		Insect Lac		(Bowen and Moser 1968: 89-132)
AFM	1861	Arrow		Yaqui (Yoeme)	Cane, wood, feather	1953 CE	Insect Lac - possible, requires further analysis		
AFM	2116 AB	Arrows (2)		Seri (Comcáac)	Cane, hawk feather, deer sinew, Tachardiella larreae	1951 CE	Insect Lac - possible, requires further analysis	Tecomate Camp, Tiburon Island, Sonora, Mexico	
AFM	2115 ABC	Arrows (3)		Seri (Comcáac)	Cane, feather	1953 CE	Insect Lac - possible, requires further analysis	Desemboque, Sonora, Mexico	
AMNH	H/ 5144	Scraper, inlaid #9	Pueblo Bonito, Chaco Canyon	Ancestral Puebloan	Bone, stone (turquoise, jet) resin	850-1140 CE	Insect Lac - possible, requires further analysis	San Juan County, NM	(2021 Artifact Query, March 7, 2021. The Chaco Research Archive (http://www.chacoarchive.org); Pepper 1905. :183-197; Pepper 1909:196-252; Pepper 1920; Anderson 2019)

AMNH	H/10426	Carving, frog	Pueblo Bonito, Chaco Canyon	Ancestral Puebloan	Stone (turquoise, jet) resin	850-1140 CE	Insect Lac - possible, requires further analysis	San Juan County, NM	2021 Artifact Query, March 7, 2021. The Chaco Research Archive (http://www.chacoarchive.org): Pepper, 1905:183-197 (Plate XVII; p.192); Pepper, 1909: 196-252; Pepper 1920)
AMNH	H/10418	Figurine, animal form	Pueblo Bonito, Chaco Canyon	Ancestral Puebloan	Shell, bone, stone (turquoise), resin	1050-1250 CE	Insect Lac - possible, requires further analysis	San Juan County, NM	(2021 Artifact Query, March 7, 2021. The Chaco Research Archive (http://www.chacoarchive.org); Pepper, 1905:183-197; Pepper 1909:196-252 Fig 4, p. 229; Pepper 1920: 176)
AMNH	50.1/ 4886	Rattle		Cocopah (Cucapá)	Gourd, cloth, resin?	1911 CE collected	Insect Lac - possible, requires further analysis	Lerdo, Colorado River, Sonora, Mexico	(Lumholtz 1912)
AMNH	50 / 6118	Rattle		Luiseño or Diegueño?	Gourd, wood, twine, pigment, pitch?	1905	Insect Lac - possible, requires further analysis	Southern California, Basin, Peninsula, Southwest region	(Du Bois 1908)
AMNH	50 / 6119	Rattle		Luiseño or Diegueño?	Gourd, cane, resin	1905	Insect Lac - possible, requires further analysis	Southern California, Basin, Peninsula, Southwest region	(Du Bois 1908)
AMNH	50.1/ 4875	Arrow		Papago (Tohono O'odham)	Wood, feathers, pigment, glass	1911 CE collected	Insect Lac - possible, requires	Nariz, Sonora, Mexico	(Lumholtz 1912)

					(obsidian), resin?		further analysis		
AMNH	50.1/ 4868	Arrow		Papago (Tohono O'odham)	Wood, feathers, pigment, glass (obsidian), resin?	1911 CE collected	Insect Lac - possible, requires further analysis	Nariz or Sonoita (Sonoyta), Sonora, Mexico	(Lumholtz 1912)
AMNH	50.1/ 5157	Awl		Papago (Tohono O'odham)	Metal, pitch?	1911 CE collected	Insect lac	San Xavier Mission, Pima Co., AZ	(Kissell 1916: 203-206)
AMNH	50.1/ 4441	Awl		Papago (Tohono O'odham)	Metal, pitch?	1911 CE collected	Insect lac	San Xavier Mission, Pima Co., AZ	(Lumholtz 1912: 223)
AMNH	50.1/ 4562	Awl		Papago (Tohono O'odham)	Metal, pitch?	1911 CE collected	Insect lac	"Krilpat Vaaka Village" Possibly Va'aki Village, AZ	(Lumholtz 1912: 223)
AMNH	50.1/ 5216	Awl		Papago (Tohono O'odham)	Metal, pitch?	1911 CE collected	Insect lac	Santa Rosa, Tohono O'odham Nation, Pima Co., AZ	(Kissell 1916: 203-206)
AMNH	50.1/ 5217	Awl		Papago (Tohono O'odham)	Metal, pitch?	1911 CE collected	Insect lac	Santa Rosa, Tohono O'odham Nation, Pima Co., AZ	(Kissell 1916: 203-206)
AMNH	50.1/ 5154	Coloring material, red		Papago (Tohono O'odham)	Wood (insect lac on creosote bush)	1911 CE collected	Insect lac	San Xavier, Pima Co., AZ	(Kissell 1916)
AMNH	50.1/ 4904	Container, gold dust		Papago (Tohono O'odham)	Cane, leather, resin or pigment sealant	1911 CE collected	Insect Lac - possible, requires further analysis	Quitovac, Sonora, Mexico	(Lumholtz 1912: 183)
AMNH	50.1/ 5243	Gum, handle making		Papago (Tohono O'odham)	Wood, gum (insect lac on stem)	1911 CE collected	Insect lac	Santa Rosa, Tohono O'odham Nation, Pima Co., AZ	(Kissell 1916: 203-206)
AMNH	50.1/ 4646	Gum, pot mending		Papago (Tohono O'odham)	Wood (greasewood) gum, plant fiber	1911 CE collected	Insect lac	Arizona	(Lumholtz 1912: 223)

					(insect lac on stem)				
AMNH	50.1/ 5161	Knife, for basket making		Papago (Tohono O'odham)	Wood, metal, pitch	1911 CE collected	Insect Lac - probable	San Xavier Mission, Pima Co., AZ	(Kissell 1916: 203-206)
AMNH	50.1/ 5162	Knife, for basket making		Papago (Tohono O'odham)	Metal, pitch?	1911 CE collected	Insect lac	San Xavier Mission, Pima Co., AZ	(Kissell 1916: 203-206)
AMNH	50.1/ 4442	Knife, for cutting willow		Papago (Tohono O'odham)	Metal, pitch?	1911 CE collected	Insect lac	San Xavier Mission, Pima Co., AZ	(Lumholtz 1912: 223)
AMNH	50.1/ 4535	Rattle		Papago (Tohono O'odham)	Gourd, wood, resin or pigment?	1911 CE collected	Insect Lac - possible, requires further analysis	"Cav-Va-Xiac" Village, now known as Cobabi (*Kaav Vavhia)* East of Santa Rosa, Pima Co. AZ	(Lumholtz 1912)
AMNH	50.1/ 5270	Awl		Pima (Akimel O'odham)	Metal, "gum" insect lac	1911 CE collected	Insect lac	Sweetwater Village, Gila River Indian Community, Pinal Co., AZ	(Kissell 1916: 203-206 Fig 49f)
AMNH	29.0/ 1602	Vessel, pottery		Pima (Akimel O'odham)	Ceramic, insect lac	1911 CE collected	Insect lac	Graham County, AZ	(Lumholtz 1912: 223)
AMNH	65 / 833	Rattle		Tarahumara (Rarámuri)	Gourd, wood, resin	1890s	Insect Lac - possible, requires further analysis	Carichic, Chihuahua, Mexico	(Lumholtz 1902)
AMW	1-10990	Jar, Pottery		Cahuilla	Ceramic, resin	1907 CE collected	Insect Lac - possible, requires further analysis	Torres Martinez Reservation, Riverside Co. Imperial Co., CA	(Kroeber 1908 plate 9)
AMW	1-11106	Mortar		Cahuilla	Stone, Basketry, plant fiber, resin	1907 CE collected	Insect Lac - possible, requires	Morongo Reservation, Riverside Co. Ca	(Kroeber 1908:43)

							further analysis		
AMW	1-69175	Olla, pottery		Cahuilla	Ceramic, resin	1915 CE collected	Insect Lac - possible, requires further analysis	Mission Creek Canyon, Riverside Co., CA	
AMW	1-11013	Rattle		Cahuilla	Wood, gourd, leather, resin	1907 CE collected	Insect Lac - possible, requires further analysis	Torres Martinez Reservation, Riverside Co. Imperial Co., CA	(Kroeber 1908)
AMW	3127	Knife		Ancestral Puebloan	Stone, wood, adhesive resin	1100-1150 CE	Insect Lac - probable	Mesa House Ruin, Clark Co., NV	(Shellbach 1930:53-74)
AMW	6F865	Knife, hafted	Gypsum Cave	Prehistoric Southwest			Insect Lac - probable	NV	(Gilreath et al. 2009: 46)
AMW	491.P.3136	Awl		Panamint (Koso, Timbisha Shoshone)/ Great Basin	Cactus spine, insect lac	late1800s to early 1900s	Insect Lac	N/A	
ASM	E-3086-X-8	Arrow Shaft		Maricopa (Piipaash)	Wood, metal, sinew, stone, insect lac	1956 CE	Insect lac	Maricopa Co., AZ	
ASM	22608	Plate, Pottery		Maricopa (Piipaash)	Ceramic, insect lac	1900 CE	Insect Lac	Gila River Indian Community, Laveen, Maricopa Co., AZ	
ASM	GP-39741	Arrow foreshaft, paint		Prehistoric, Northern Sierra Province	Plant material (Phragmites)	c. 1350 CE-1500CE	Insect Lac	Chihuahua, Mexico	
ASM	A-22445-X-3	Etched shell fragment	Hodges Ruin	Hohokam, Tucson Province	Shell (Laevicardium Elatum) Insect lac	950-1300 CE	Insect Lac	Tucson Basin, Pima Co. AZ	(Kelly 1978)

ASM	A-39022	Jar, Pottery	SE of Cibola, Arizona	Lowland Patayan, Lower Colorado Province	Ceramic, insect lac	900-1400 CE	Insect Lac	Colorado River, Cibola Valley, Yuma Co., AZ	
ASM	A-36794	Jar, Pottery	"Picu Mts.---Road To Golondrina."	Trincheras? Protohistoric ?	Ceramic, insect lac	700-1150 CE	Insect Lac	Sierra Picu, Pitiquito Co., Sonora, Mexico	(Claypatch 2018:35)
ASM	A-2700	Jar, Pottery	"Small Cave At Base Of Harquahala Peak...East Of Harquahala Peak."	Upland Patayan	Ceramic, insect lac	700 - 1890 CE	Insect Lac	Harquahala Mountains, Maricopa Co., AZ	
ASM	E-2373	Jar, Pottery	"Cave, Maricopa County; Ca 12 Miles Northeast Of Gila Bend."	Lowland Patayan, Lower Colorado Province	Ceramic, insect lac	651 - 1890 CE	Insect Lac	Maricopa Mountains, Maricopa Co., AZ	
ASM	17410	Jar, Pottery	"Pima Reservation."	Lowland Patayan, Lower Colorado Province	Ceramic, insect lac	650 - 1890 CE	Insect Lac	Gila River Indian Reservation; Salt-Gila Basin, Maricopa Co., AZ	
ASM	E-2374	Jar & lid, Pottery	"Cave, Maricopa County; Ca 12 Miles Northeast Of Gila Bend."	Lowland Patayan, Lower Colorado Province	Ceramic, insect lac	650 - 1890 CE	Insect Lac	Maricopa Mountains, Maricopa Co., AZ	
ASM	13106	Arrow	Cave Creek Village	Mogollon San Simon Province	Wood, insect lac	50 CE-400 CE?	Insect Lac	Cave Creek, Chiricahua Mountains, Cochise County, AZ	(Sayles 1945)
ASM	A-13800	Knife	Broken Flute Cave	Basketmaker III, Prayer	Bone (Artiodactyla), sinew, stone	354 CE-652 CE	Insect Lac	Atahonez Wash, Apache County, AZ	(Morris1980. Fig. 34)

				Rock Province	(Chalcedony), insect lac				
ASM	1989-42-1	Jar, Pottery		Lowland Patayan, Lower Colorado Province	Ceramic, insect lac	1440-1640 CE	Insect Lac	Lower Colorado River, Yavapai Co., AZ	(Macnider 1990 Fig. 9, Fig. 24)
ASM	1984-49-1	Jar, Pottery	Wellton Hills Cache	Lowland Patayan II; Lower Gila Province	Ceramic, insect lac, pine resin	1420 - 1650 CE	Insect Lac	Coyote Wash, Wellton Hills, Yuma Co., AZ	
ASM	A-8899	Mosaic pendant	Tonto Cliff Dwellings Lower Ruin	Salado, Tonto-Roosevelt Province	Wood, stone (turquoise) adhesive resin	1350-1450 CE	Insect Lac	Cholla Canyon, Gila Co., AZ	(Steen et al. 1962; Dubin 1999 Fig 1049, p. 504)
ASM	A-17169-Y	Arrow foreshaft, tenon	Red Bow Cliff Dwelling	Mogollon, Point of Pines Province	Wood, sinew, insect lac, pine resin, pigment	1336 CE -1400 CE	Insect Lac	Graham County, AZ	(Gifford 1980: 94-95, Fig. 73s; Adams 1990)
ASM	A-17168-X-9	Arrow foreshaft, hafting	Red Bow Cliff Dwelling	Mogollon, Point of Pines Province	Wood, sinew, insect lac	1334 CE -1400 CE	Insect Lac	Graham County, AZ	(Gifford 1980: 94-95, Fig. 73s; Adams 1990)
ASM	A-17168-X-8	Arrow foreshaft, hafting	Red Bow Cliff Dwelling	Mogollon, Point of Pines Province	Wood, sinew, insect lac, pigment	1332 CE -1400 CE	Insect Lac	Graham County, AZ	(Gifford 1980: 94-95, Fig. 73s; Adams 1990)
ASM	A-17168-X-7	Arrow foreshaft, hafting	Red Bow Cliff Dwelling	Mogollon, Point of Pines Province	Wood, insect lac	1331 CE -1400 CE	Insect Lac	Graham County, AZ	((Gifford 1980: 94-95, Fig. 73s; Adams 1990)
ASM	A-17168-X-4	Arrow foreshaft, hafting	Red Bow Cliff Dwelling	Mogollon, Point of Pines Province	Wood, sinew, insect lac	1330 CE -1400 CE	Insect Lac	Graham County, AZ	(Gifford 1980: 94-95, Fig. 73s; Adams 1990)
ASM	A-17168-X-3	Arrow foreshaft, hafting	Red Bow Cliff Dwelling	Mogollon, Point of Pines Province	Wood, sinew, insect lac	1328 CE -1400 CE	Insect Lac	Graham County, AZ	(Gifford 1980: 94-95, Fig. 73s; Adams 1990)

ASM	A-17168-X-2	Arrow foreshaft, tenon	Red Bow Cliff Dwelling	Mogollon, Point of Pines Province	Wood, sinew, stone (obsidian), insect lac	1327 CE -1400 CE	Insect Lac	Graham County, AZ	(Gifford 1980: 94-95, Fig. 73s; Adams 1990)
ASM	A-17168-X-2	Arrow foreshaft, hafting	Red Bow Cliff Dwelling	Mogollon, Point of Pines Province	Wood, sinew, stone (obsidian), insect lac	1326 CE -1400 CE	Insect Lac	Graham County, AZ	(Gifford 1980: 94-95, Fig. 73s; Adams 1990)
ASM	A-17167	Arrow foreshaft, hafting	Red Bow Cliff Dwelling	Mogollon, Point of Pines Province	Wood, insect lac	1325 CE -1400 CE	Insect Lac	Graham County, AZ	((Gifford 1980: 94-95, Fig. 73s; Adams 1990)
ASM	A-17168-X-1	Arrow foreshaft, hafting	Red Bow Cliff Dwelling	Mogollon, Point of Pines Province	Wood, sinew, insect lac	1325 CE -1400 CE	Insect Lac	Graham County, AZ	(Gifford 1980: 94-95, Fig. 73s; Adams 1990)
ASM	1997-194-15-xx	Mosaic pendant tesserae	Homestead Site	Hohokam, Gila Bend Province	Shell, stone (turquoise and argillite), adhesive resin	1300-1500 CE	Insect Lac	Arlington Valley, AZ	(Wasley and Johnson 1965 Fig. 84. P. 107)
ASM	GP-5765	Mosaic pendant	Chavez Pass Ruin	Sinagua/Chevelon-Chavez Province	Animal/Shell / , Stone/Turquoise /	1300-1400 CE	Insect Lac	Coconino Co., AZ	(Fewkes 1904:.86)
ASM	2016-31-70	Frog effigy mosaic	Homol'ovi I	Ancestral Puebloan	Shell (Glycymeris), stone (turquoise and argillite), insect lac	1285 - 1400 CE	Insect Lac	Little Colorado River Valley, Navajo Co., AZ	(Adams 2002)
ASM	6748	Mosaic pendant	Kinishba	Mogollon, White River Province	Shell (Dosinia), stone (turquoise) & Spondylus shell tesserae; insect lac adhesive	1275 - 1400 CE	Insect lac - probable	Gila County, AZ USDI, BIA, Fort Apache Indian Reservation	
ASM	1787	Handle, Hafting	Scaffold House	Ancestral Puebloan, Kayenta Province	Wood, insect lac, pigment	1250 CE-1300 CE	Insect Lac	Navajo County, AZ	

ASM	26365	Mosaic pendant	Kinishba	Mogollon, White River Province	Shell (Glycymeris), stone (turquoise), insect lac	1225 CE -1425 CE	Insect Lac	Gila County,	(Cummings 1940)
ASM	GP-9895	Mosaic pendant	Keystone Ruin	Salado, Tonto-Roosevelt Province	Glycymeris shell, turquoise & argillite	1200-1300 CE	Insect Lac	Porter Spring, Gila Co., AZ	
ASM	GP-4974-x	Arrow, tenon	Greenwood Cave	Mogollon, Upper Gila Province	Wood, insect lac	1000 CE-1250 CE	Insect Lac	Grant County, NM	(Cosgrove 1947)
ASM	1544	Pendant		Prehistoric, San Juan Province	Bear claw, leather, insect lac	< 1915 CE	Insect lac	San Juan County, UT	
ASM	1184	Handle, Hafting	Chilchinta-boko	Ancestral Puebloan, Kayenta Province	Wood, insect lac		Insect Lac	Coconino County, AZ	
ASM	5730	Biface		Ancestral Puebloan, Kayenta Province	Stone, wood, insect lac		Insect Lac	Navajo County, AZ	
ASM	6546-X	Gaming Piece	Dome Cave	Ancestral Puebloan, Kayenta Province	Bone, insect lac		Insect Lac	Coconino County, AZ	
ASM	6547-X	Gaming Piece	Dome Cave	Ancestral Puebloan, Kayenta Province	Bone, insect lac		Insect Lac	Coconino County, AZ	
ASM	A-39044	Sherd with resin	Ventana Cave	Hohokam	Ceramic, insect lac		Insect Lac	Castle Mountains, AZ	(Haury 1950)
ASM	A-8824 x	Arrow fragments	Ventana Cave	Hohokam	Wood, sinew, insect lac		Insect Lac	Castle Mountains, AZ	(Haury 1950)
ASM	A-8824 x	Arrow notch	Ventana Cave	Hohokam	Wood, sinew, insect lac		Insect Lac	Castle Mountains, AZ	(Haury 1950)
ASM	A-75	Arrow, notch	Bat Cave	Hohokam, Papagueria Project	Wood, insect lac		Insect Lac	Papagueria, South Mountain,	(Haury 1950:19)

								Pima County, AZ	
ASM	A-78	Arrow, notch	Bat Cave	Hohokam, Papagueria Project	Wood, paint, insect lac		Insect Lac	Papagueria, South Mountain, Pima County, AZ	(Haury 1950:19)
ASM	2399	Ball	Casa Blanca	Hohokam, Piman?, Salt-Gila Province	Bone, insect lac		Insect Lac	Gila River, Pinal County, AZ	
ASM	A-22922	Ball		Hohokam, Piman?, Salt-Gila Province	Stone or wood, Insect lac		Insect Lac	Gila Butte, Pinal County, AZ	
ASM	A-41156	Ball	Sacaton vicinity	Hohokam, Piman?, Salt-Gila Province	Stone or wood, insect lac		Insect Lac	Sacaton vicinity, Pinal County, AZ	
ASM	18487	Arrow mainshaft fragment	Tanque Verde Cave	Hohokam, Tucson Province	Plant material (Phragmites); sinew, insect lac		Insect Lac	Tanque Verde Mountains, Pima County, AZ	
ASM	A-8843-x	Stick lac	Ventana Cave	Hohokam/Tohono O'odham	Larrea tridentata, Tachardiella larreae		Insect Lac	Castle Mountains, AZ	(Haury 1950:Pl. 19 a-h)
ASM	A-8847	Lac, raw material	Ventana Cave	Hohokam/Tohono O'odham	Tachardiella larreae		Insect Lac	Castle Mountains, AZ	(Haury 1950:443)
ASM	B-89	Stick lac	Ventana Cave	Hohokam/Tohono O'odham	Larrea tridentata, Tachardiella larreae		Insect Lac	Castle Mountains, AZ	(Haury 1950: 161-169)
ASM	A-75	Arrow, black paint	Bat Cave	Hohokam, Papagueria Project	Wood, paint, insect lac		Insect Lac	Papagueria, South Mountain, Pima County, AZ	(Haury 1950:19)
ASM	2013-136-1 ab	jar, Pottery	Bullhead City vicinity,	Lowland Patayan	Ceramic, insect lac		Insect Lac	Mohave County, AZ	(Stone 1987)

			Colorado River						
ASM	A-10884-C	Arrow foreshaft	Guano Cave	Mogollon, Chiricahua Province	wood, plant material, insect lac		Insect Lac	Cochise County, AZ	
ASM	A-10884-D	Arrow foreshaft	Guano Cave	Mogollon, Chiricahua Province	wood, plant material, sinew, feather, insect lac, pigment		Insect Lac	Cochise County, AZ	
ASM	A-12456-X-1	Hafted biface	Point of Pines Pueblo	Mogollon, Point of Pines Province	Stone (chert), wood, insect lac		Insect Lac	Graham County, AZ	(Haury 1989)
ASM	23449	Arrow fragment		Prehistoric Southwest	Wood, cane, cotton, sinew, insect lac		Insect Lac	Southwest unknown	
ASM	A-3391-X-1	Bottle, gourd	Cave In Sierra De La Gallina	Prehistoric, Rio Sonora Province	Gourd, insect lac		Insect Lac	Sierra de la Gallina, Sahuaripa County, Sonora, Mexico	(Hinton 1959)
ASM	A-3392-X-1	Bottle, gourd	Cave In Sierra De La Gallina	Prehistoric, Rio Sonora Province	Gourd, insect lac		Insect Lac	Sierra de la Gallina, Sahuaripa County, Sonora, Mexico	
ASM	A-3393-X-1	Bottle, gourd	Cave In Sierra De La Gallina	Prehistoric, Rio Sonora Province	Gourd, insect lac		Insect Lac	Sierra de la Gallina, Sahuaripa County, Sonora, Mexico	
ASM	A-3394-X-1	Bottle, gourd	Cave In Sierra De La Gallina	Prehistoric, Rio Sonora Province	Gourd, insect lac		Insect Lac	Sierra de la Gallina, Sahuaripa County, Sonora, Mexico	
ASM	GP-52739-X-3 or 4?	Ball		Pima (Akimel O'odham)	Wood, glass, metal, shell, insect lac	1934 CE	Insect lac	Snaketown, Pinal Co., AZ	

ASM	GP-52739-X-5	Ball		Pima (Akimel O'odham)	Wood, glass, metal, shell, insect lac	1934 CE	Insect lac	Snaketown, Pinal Co., AZ	
ASM	E-3474	Jar, Pottery		Pima (Akimel O'odham)	Ceramic, insect lac	1900 CE	Insect Lac	Arizona	
ASM	E-1036	Amulet		Seri (Comcáac)	Cotton, insect lac	1941 CE	Insect Lac	Desemboque, Sonora, Mexico	(The Gwyneth Harrington Papers, 1934-1962. Arizona State Museum Archives. MS 24)
ASM	E-980	Amulet		Seri (Comcáac)	Insect lac, cotton, animal (hawk claw)	1941 CE	Insect lac	Tiburon Island, Sonora, Mexico	(The Gwyneth Harrington Papers, 1934-1962. Arizona State Museum Archives. MS 24)
ASM	2019-183-21	Amulet		Seri (Comcáac)	Insect lac (Csipx), string		Insect Lac	Sonora, Mexico	(Felger and Moser 1985: 141)
ASM	2019-183-22	Amulet		Seri (Comcáac)	Insect lac (Csipx), string		Insect Lac	Sonora, Mexico	(Felger and Moser 1985: 141)
ASM	2019-183-23	Amulet		Seri (Comcáac)	Insect lac (Csipx), string		Insect Lac	Sonora, Mexico	(Felger and Moser 1985: 141)
ASM	2019-183-24	Amulet		Seri (Comcáac)	Insect lac (Csipx), string		Insect Lac	Sonora, Mexico	(Felger and Moser 1985: 141)
ASM	2019-183-25	Amulet		Seri (Comcáac)	Insect lac (Csipx), string		Insect Lac	Sonora, Mexico	((Felger and Moser 1985: 141)
ASM	E-6127-X-1	Arrow Shaft		Seri (Comcáac)	Wood, metal, sinew, feather, insect lac	1964 CE	Insect lac	Desemboque, Sonora, Mexico	
ASM	E-6127-X-2	Arrow Shaft		Seri (Comcáac)	Wood, metal, sinew, feather, insect lac	1965 CE	Insect lac	Desemboque, Sonora, Mexico	
ASM	E-6127-X-3	Arrow Shaft		Seri (Comcáac)	Wood, metal, sinew, feather, insect lac	1966 CE	Insect lac	Desemboque, Sonora, Mexico	
ASM	E-8628-X-1	Arrow, hafting		Seri (Comcáac)	Plant Material (cotton, cane), wood	1930 CE	Insect Lac	Sonora, Mexico	

					(ironwood), sinew, feather, stone, insect lac				
ASM	E-8628-X-2	Arrow, hafting		Seri (Comcáac)	Plant Material (cotton, cane), wood (ironwood), sinew, feather, stone, insect lac	1930 CE	Insect Lac	Sonora, Mexico	
ASM	1997-59-11	Carving, bird		Seri (Comcáac)	Wood, insect lac	1970	Insect lac	Desemboque, Sonora, Mexico	(Felger and Moser 1985: 176)
ASM	2000-136-30	Carving, Dolphin		Seri (Comcáac)	Wood, insect lac	1960	Insect lac	Sonora, Mexico	(Felger and Moser 1985: 176; R. Michelson Archives, Arizona State Museum Archives)
ASM	2000-136-40	Carving, Dolphin		Seri (Comcáac)	Wood, insect lac	1960	Insect lac	Sonora, Mexico	(Felger and Moser 1985: 176; R. Michelson Archives, Arizona State Museum Archives)
ASM	2000-136-42	Carving, Eel		Seri (Comcáac)	Wood, insect lac	1960	Insect lac	Sonora, Mexico	(Felger and Moser 1985: 176; R. Michelson Archives, Arizona State Museum Archives)
ASM	1982-37-2	Carving, Female		Seri (Comcáac)	Wood, insect lac	1968	Insect lac	Kino Bay, Sonora, Mexico	(Felger and Moser 1985: 176)
ASM	1997-59-13	Carving, louse		Seri (Comcáac)	Wood, insect lac	1970	Insect lac	Desemboque, Sonora, Mexico	(Felger and Moser 1985: 176)
ASM	2000-136-34	Carving, Manta Ray		Seri (Comcáac)	Wood, insect lac	1960	Insect lac	Sonora, Mexico	(Felger and Moser 1985: 176; R. Michelson Archives, Arizona State Museum Archives)

ASM	4/11/81	Carving, Porpoise		Seri (Comcáac)	Wood, insect lac	1970	Insect lac	N/A	Felger, Richard and (Felger and Moser 1985: 176)
ASM	E-7912	Carving, Quail		Seri (Comcáac)	Wood, insect lac	1968	Insect lac	Desemboque, Sonora, Mexico	(Felger and Moser 1985: 176)
ASM	2000-136-36	Carving, Sea Turtle		Seri (Comcáac)	Wood, insect lac	1960	Insect lac	Sonora, Mexico	(Felger and Moser 1985: 176; R. Michelson Archives, Arizona State Museum Archives)
ASM	E-8180	Carving, Seal		Seri (Comcáac)	Wood, insect lac	1969	Insect lac	Punta Chueca, Sonora, Mexico	Felger and Moser 1985: 176)
ASM	2000-136-41	Carving, Swordfish		Seri (Comcáac)	Wood, insect lac	1960	Insect lac	Sonora, Mexico	(Felger and Moser 1985: 176; R. Michelson Archives, Arizona State Museum Archives)
ASM	2000-136-43	Carving, Swordfish		Seri (Comcáac)	Wood, insect lac	1960	Insect lac	Sonora, Mexico	(Felger and Moser 1985: 176; R. Michelson Archives, Arizona State Museum Archives)
ASM	2000-136-30	Figure, Dolphin		Seri (Comcáac)	Wood (ironwood), insect lac	1960 CE	Insect lac	Sonora, Mexico	(Felger and Moser 1985: 176; R. Michelson Archives, Arizona State Museum Archives)
ASM	2000-136-40	Figure, Dolphin		Seri (Comcáac)	Wood (ironwood), insect lac	1960 CE	Insect lac	Sonora, Mexico	(Felger and Moser 1985: 176; R. Michelson Archives, Arizona State Museum Archives)
ASM	2000-136-42	Figure, Eel		Seri (Comcáac)	Wood (ironwood), insect lac	1960 CE	Insect lac	Sonora, Mexico	(Felger and Moser 1985: 176; R. Michelson

									Archives, Arizona State Museum Archives)
ASM	E-9263	Figure, Frog		Seri (Comcáac)	Wood (ironwood), insect lac	1969 CE	Insect lac	Desemboque, Sonora, Mexico	(Felger and Moser 1985: 176; R. Michelson Archives, Arizona State Museum Archives)
ASM	2000-136-34	Figure, Manta Ray		Seri (Comcáac)	Wood (ironwood), insect lac	1960 CE	Insect lac	Sonora, Mexico	(Felger and Moser 1985: 176; R. Michelson Archives, Arizona State Museum Archives)
ASM	2000-136-36	Figure, Sea Turtle		Seri (Comcáac)	Wood (ironwood), insect lac	1960 CE	Insect lac	Sonora, Mexico	(Felger and Moser 1985: 176; R. Michelson Archives, Arizona State Museum Archives)
ASM	2000-136-41	Figure, Swordfish		Seri (Comcáac)	Wood (ironwood), insect lac	1960 CE	Insect lac	Sonora, Mexico	(Felger and Moser 1985: 176; R. Michelson Archives, Arizona State Museum Archives)
ASM	2000-136-43	Figure, Swordfish		Seri (Comcáac)	Wood (ironwood), insect lac	1960 CE	Insect lac	Sonora, Mexico	(Felger and Moser 1985: 176; R. Michelson Archives, Arizona State Museum Archives)
ASM	2019-183-26-x-1 - x-4	Formed pieces of lac		Seri (Comcáac)	Insect lac (Csipx), Tachardiella larreae		Insect Lac	Sonora, Mexico	(Felger and Moser, 1985:141,326-327)
ASM	E-8819	Glue		Seri (Comcáac)	Insect lac	1930 CE	Insect Lac	Sonora, Mexico	

ASM	2010-462-13	Harpoon		Seri (Comcáac)	Wood, cord, metal, insect lac	c. 1950 CE	Insect Lac	Sonora, Mexico	(Felger and Moser, 1985:128-130; Sheridan and Parezo, Nancy, Paths of Life 1996: 206)
ASM	2010-462-14	Harpoon		Seri (Comcáac)	Plant material, insect lac	c. 1950 CE	Insect Lac	Desemboque, Sonora, Mexico	(Felger and Moser, 1985:128-130; Sheridan and Parezo, Nancy, Paths of Life 1996: 206)
ASM	E-5235	Harpoon point		Seri (Comcáac)	Wood, cotton, metal, insect lac	1955 CE	Insect lac	Desemboque, Sonora, Mexico	
ASM	E-1062	Harpoon point, miniature		Seri (Comcáac)	Wood, cotton, metal, insect lac	1941 CE	Insect lac	Tiburon Island, Sonora, Mexico	The Gwyneth Harrington Papers, 1934-1962. Arizona State Museum Archives. MS 24
ASM	E-8682	Jar, Pottery		Seri (Comcáac)	Ceramic, insect lac	1967 CE	Insect Lac	Sonora, Mexico	
ASM	E-9940	Jar, Pottery		Seri (Comcáac)	Ceramic, insect lac	1971 CE	Insect Lac	Desemboque, Sonora, Mexico	(Felger and Moser 1985:355-356)
ASM	2019-183-6	Stick lac (Tachardiella larreae)		Seri (Comcáac)	Tachardiella larreae on Larrea tridentata twigs		Insect Lac	Desemboque, (area) Sonora, Mexico	(Felger and Moser 1985: 386, fig. 17.6)
ASM	1984-9-45	Awl, resin handle	Nolic	Tohono O'odham	Metal (iron), insect lac	1880 CE	Insect Lac	Ko Vaya Hills, Pima County AZ	(Doelle, et al. 1983)
ASM	1984-9-46	Awl, resin handle	Nolic	Tohono O'odham	Metal (iron), insect lac	1881 CE	Insect Lac	Ko Vaya Hills, Pima County AZ	(Doelle, et al. 1983)
ASM	E-3752	Jar, Pottery	"Cave About 40 Miles From Ajo, Ariz., Towards Sells." Quijotoa Mountains	Tohono O'odham	Ceramic, insect lac	< 1959 CE	Insect Lac	Quijotoa Mountains, Pima Co., AZ	

ASM	1980-15-1	Jar, Pottery		Tohono O'odham	Ceramic, metal, insect lac	1880 CE	Insect Lac	Arizona	(Fontana et al. 1962: 80-81, 118)
ASM	4017-X-2	Jar, Pottery		Tohono O'odham	Ceramic, insect lac	1880 CE	Insect Lac	Arizona	
ASM	E-5698	Jar, Pottery		Tohono O'odham	Ceramic, insect lac	1880 CE	Insect Lac	Arizona	
ASM	E-3473	Jar, Pottery		Tohono O'odham	Ceramic, insect lac	1900 CE	Insect Lac	Tohono O'odham Indian Reservation, Pima Co. AZ	
ASM	E-3908	Jar, Pottery		Tohono O'odham	Ceramic, insect lac	1900 CE	Insect Lac		
ASM	E-2504	Jar, Pottery		Tohono O'odham	Ceramic, insect lac	1902 CE	Insect Lac	Flat Yellow Mountain, Pima Co., AZ	
ASM	E-5336-A	Jar, Pottery		Tohono O'odham	Ceramic, insect lac	1910 CE	Insect Lac	Big Fields, Tohono O'odham Indian Reservation, Pima Co., AZ	
ASM	1985-58-9	Jar, Pottery		Tohono O'odham	Ceramic, insect lac	1920 CE	Insect Lac	Pima Co., AZ	
ASM	E-7631	Jar, Pottery		Tohono O'odham	Ceramic, insect lac	1920 CE	Insect Lac	Tohono O'odham Indian Reservation, Pima Co. AZ	
ASM	E-7636	Jar, Pottery		Tohono O'odham	Ceramic, insect lac	1920 CE	Insect Lac	Tohono O'odham Indian Reservation, Pima Co. AZ	
ASM	E-3906	Jar, Pottery		Tohono O'odham	Ceramic, insect lac	1930 CE	Insect Lac	Tohono O'odham Indian Reservation, Pima Co. AZ	
ASM	E-7672	Jar, Pottery		Tohono O'odham	Ceramic, insect lac	1930 CE	Insect Lac	Tohono O'odham Indian Reservation, Pima Co. AZ	(Fontana et al. 1962: 34:Figs. 29,31)
ASM	2005-666-46	Jar, Pottery		Tohono O'odham	Ceramic, unknown resin	1939 - 1995 CE	Insect lac	Tohono O'odham Indian	

								Reservation, Pima Co. AZ	
ASM	26063-X-7	Jar, Pottery		Tohono O'odham	Ceramic, insect lac	1939 CE	Insect Lac	Pima Co., AZ	(Fontana et al. 1962: 34)
ASM	2005-666-17	Jar, Pottery		Tohono O'odham	Ceramic, insect lac	1939-1995 CE	Insect Lac	Tohono O'odham Indian Reservation, Pima Co. AZ	
ASM	2005-666-40	Jar, Pottery		Tohono O'odham	Ceramic, insect lac	1939-1995 CE	Insect Lac	Tohono O'odham Indian Reservation, Pima Co. AZ	
ASM	E-3907	Jar, Pottery		Tohono O'odham	Ceramic, insect lac	1940 CE	Insect Lac	Tohono O'odham Indian Reservation, Pima Co. AZ	
ASM	E-7647	Jar, Pottery		Tohono O'odham	Ceramic, insect lac	1940 CE	Insect Lac	Tohono O'odham Indian Reservation, Pima Co. AZ	
ASM	E-7640	Jar, Pottery		Tohono O'odham	Ceramic, insect lac	1955 CE	Insect Lac	Tohono O'odham Indian Reservation, Pima Co. AZ	
ASM	1980-15-2	Jar, Pottery		Tohono O'odham	Ceramic, insect lac	1970 CE	Insect Lac	Arizona	
ASM	E-3640-A	Lac for mending pottery		Tohono O'odham	Tachardiella larreae on Larrea tridentata twigs	1958 CE	Insect lac	Tohono O'odham Indian Reservation, Sells District, Pima Co. AZ	
ASM	3099	Rattle		Tohono O'odham	Wood, gourd, metal, insect lac	1917 CE	Insect lac	Pima County, AZ	
ASM	A-3710	Stick with resin		Tohono O'odham	Larrea tridentata, Tachardiella larreae		Insect Lac	Santa Rosa Wash, Pima County, AZ	
ASM	GP-52609	Jar, Pottery		Unknown	Ceramic, insect lac	< 1951	Insect Lac		

ASM	23106-x-23	Arrow Shaft		Yaqui (Yoeme)	Wood (ironwood), sinew, cane, metal, insect lac	Cummings era	Insect lac	United States	
ECPR	8136, 8137	Composite object (Ornament)	Edge of the Cedars	Ancestral Puebloan	Shell, turquoise, adhesive resin		Insect Lac - possible, requires further analysis	Edge of Cedars Museum, Blanding, UT	(Paul 2009)
ECPR	8302	Dice	Edge of the Cedars	Ancestral Puebloan	Bone, wood, adhesive resin		Insect Lac - possible, requires further analysis	Edge of Cedars Museum, Blanding, UT	(Paul 2009:48)
ECPR	8799-8802	Knives, hafted (4)	Westwater-Five Kiva Ruin	Ancestral Puebloan	Stone, wood, adhesive resin		Insect Lac - possible, requires further analysis	Edge of Cedars Museum, Blanding, UT	(Paul 2009:56)
FMNH	48485	Stick		Tarahumara (Rarámuri)	Insect Lac	N/A	Insect Lac	Mexico?	
MNA	NA7523.P 29-30.4G4	Atlatl spear foreshaft	Sand Dune Cave	Basketmaker	Wood, stone, sinew, resin, possibly lac	100 BCE-400 CE	Insect Lac - possible, requires further analysis	Utah, Southeastern, Northeast of Navajo Mountain	(Lindsay et al. 1968; Geib 2004; Geib, 2016)
MOCA	N/A loan?	Mosaic pendant, replica of MOCA thunderbird	Montezuma Castle	Akimel O'odham	Shell, Argillite, turquoise, insect lac		Insect Lac	Montezuma Castle National Monument	(Jackson & Valkenburga 1954)
MOCA	MOCA 462	Mosaic pendant	Montezuma Castle	Sinagua, Southern	Wood, stone (turquoise) adhesive resin	1125-1400 CE	Insect Lac - possible, requires further analysis	Montezuma Castle National Monument	(Schroeder, and Hastings 1961:13)
MOCA	MOCA 1571	Mosaic pendant, replica of MOCA 462	Montezuma Castle	Replica, modern	Wood, turquoise, coral, adhesive resin		Insect Lac - possible, requires	Montezuma Castle National Monument	(Jackson & Valkenburga 1954)

							further analysis		
MOU	1928-015-0292	Rattle		Chemehuevi	Gourd, wood, "pitch" adhesive	1903 CE	Insect Lac - possible, requires further analysis	Needles, San Bernadino Co., CA	(Hector 2018: 27; Kelly 1977)
MOU	1990-8..1A	Rattle		Cocopah	Gourd, wood, insect lac	1950 CE purchased	Insect Lac	Baja California, Mexico	(Hector 2018: 29; Kelly 1977)
MOU	1974-17-4703	Rattle		Kumeyaay	Gourd, wood, insect lac	1881 CE	Insect Lac	Southern California	
NAVA	NAVA2211	Knife hanlde		Ancestral Puebloan	Wood, resin		Insect lac - possible, requires further analysis	Keel Seel Canyon, AZ	
NAVA	NAVA287	Gaming piece		Ancestral Puebloan	Bone, resin		Insect lac - possible, requires further analysis	Navajo National Monument, AZ	
NHMLA	A.3466.34-32 E	Arrow		Chemehuevi (Nuwuwu)	Wood, feather, sinew, paint, resin/pitch	1910 CE collected	Insect Lac - probable	Needles, San Bernadino Co., CA	(Laird 1976)
NHMLA	A.3466.34-32 I	Arrow		Chemehuevi (Nuwuwu)	Wood, feather, sinew, paint, resin/pitch	1910 CE collected	Insect Lac - probable	Needles, San Bernadino Co., CA	(Laird 1976)
NHMLA	A.3466.34-34 A - D	Arrows (3)		Chemehuevi (Nuwuwu)	Wood, feather, sinew, paint, resin/pitch	1910 CE collected	Insect Lac - probable	Needles, San Bernadino Co., CA	(Laird 1976)
NHMLA	A.3466.34-35 A- D	Arrows (3)		Chemehuevi (Nuwuwu)	Wood, feather, sinew, paint, resin/pitch	1910 CE collected	Insect Lac - probable	Needles, San Bernadino Co., CA	(Laird 1976).
NHMLA	A.4515-1.6	Dart	Desha Cave, 2	Basketmaker II	Stone, wood, sinew, adhesive resin		Insect Lac - possible, requires further analysis	San Juan County, UT	(Geib & Robins 2003; Geib 2016)

NHMLA	A.4515-1.7	Dart	Desha Cave, 2	Basketmaker II	Stone, wood, sinew, adhesive resin		Insect Lac - possible, requires further analysis	San Juan County, UT	Geib & Robins 2003; Geib 2016)
NHMLA	A.4515-1.10	Dart	Desha Cave, 2	Basketmaker II	Stone, wood, sinew, adhesive resin		Insect Lac - possible, requires further analysis	San Juan County, UT	Geib & Robins 2003; Geib 2016)
NHMU	FS721.7	Projectile point	Cowboy Cave	Archaic, Late	Stone, adhesive resin	2200 - 1500 BCE	Insect Lac - possible, requires further analysis	Wayne County, UT	(Jennings et al. 1980)
NHMU	42KA274 FS14	Knife	Talus Ruin	Ancestral Puebloan	Wood, sinew, resin, stone	1100s (Lipe)	Insect Lac - possible, requires further analysis	Glen Canyon, Utah	(Lipe 1958: 6-8)
NHMU	R 4307-29	Gaming Piece	Cowboy Cave	Archaic, Terminal	Bone, adhesive resin	100-650 CE	Insect Lac - possible, requires further analysis	Wayne County, UT	(Jennings et al. 1980)
NMAI	.7/1968	Jar, Pottery		Cahuilla	Ceramic, resin	1850-1900	Insect Lac - probable	Near Banning, Malki, Morongo Reservation, Riverside Co., CA	
NMAI	.7/2268	Rattle		Cahuilla	Gourd, wood, cotton cloth, tree pitch, gum	1900-1917	Insect Lac - possible, requires further analysis	Torres Martinez Reservation, Riverside Co. Imperial Co., CA	
NMAI	.11/6875	Gum/ Pitch/ Resin		Chemehuevi	Insect Lac	1922 CE collected	Insect Lac	Chemehuevi Valley; San Bernardino County; CA	

NMAI	.11/6840	Rattle		Chemehuevi	Gourd, wood, paint, cordage, adhesive resin	1910 CE	Insect Lac - probable	Beaver Lake; Clark County; NV (Across Colorado River from Mohave City, Arizona)	
NMAI	.11/6866	Rattle		Chemehuevi	Gourd, wood, adhesive resin	1922 CE collected	Insect Lac - probable	Chemehuevi Valley, San Bernadino Co., CA	(Laird 1976)
NMAI	.11/6841	Rattle		Chemehuevi	Gourd, wood, cordage, adhesive resin	1922 CE collected	Insect Lac - probable	Beaver Lake; Clark County; NV (Across Colorado River from Mohave City, Arizona)	(Laird 1976)
NMAI	.10/3182	Rattle		Hualapai	Gourd, wood, adhesive resin	1920 CE collected	Insect Lac - probable	Kingman, Mohave Co, AZ	(Euler and Jones 1956; Colton1943)
NMAI	.10/3181	Rattle		Hualapai	Gourd, wood, paint, adhesive resin	1920 CE collected	Insect Lac - probable	Hackberry, Mohave Co., AZ	(Euler and Jones 1956; Colton1943)
NMAI	.10/3180	Rattle		Hualapai	Gourd, wood, fiber	1920 CE collected	Insect Lac - probable	Hackberry, Mohave Co., AZ	(Euler and Jones 1956; Colton1943).
NMAI	.8/2206	Rattle		Kumeyaay, Campo Band	Gourd, wood, tree pitch/gum	1918 CE collected	Insect Lac - probable	Campo, Campo Reservation; San Diego County; CA	(Gifford 1931:44)
NMAi	.8/2204	Rattle		Kumeyaay, Campo Band	Gourd, wood, tree pitch/gum	1918 CE collected	Insect Lac - probable	Campo, Campo Reservation; San Diego County; CA	(Gifford 1931:44)
NMAI	.8/2205	Rattle		Kumeyaay, Campo Band	Gourd, wood, tree pitch/gum	1918 CE collected	Insect Lac - probable	Campo, Campo Reservation; San Diego County; CA	(Gifford 1931:44)
NMAI	.8/2203	Rattle		Kumeyaay, Campo Band	Gourd, wood, tree pitch/gum	1918 CE collected	Insect Lac - probable	Campo, Campo Reservation; San Diego County; CA	(Gifford 1931:44)

NMAI	.10/2659	Ball		Mohave (Mojave)	Stone, residues?	1920 CE collected	Insect Lac - possible, requires further analysis	Parker, Colorado River Reservation; La Paz County; AZ	
NMAI	.10/2730	Gum/ Pitch/ Resin		Mohave (Mojave)	Insect lac	1920 CE collected	Insect Lac	Needles; San Bernardino County; CA	
NMAI	21/8404	Jar, Pottery		Mohave (Mojave)	Ceramic, insect lac	1951 CE purchased	Insect lac	California, Southern	(Euler and Jones 1956: 90; Spier 1955)
NMAI	.10/2637	Rattle		Mohave (Mojave)	Gourd, wood, paint, "tree pitch/gum", cordage	1920 CE collected	Insect Lac - probable	Parker, Colorado River Reservation, La Paz County, AZ	(Spier 1955:8)
NMAI	.10/2638	Rattle		Mohave (Mojave)	Gourd, wood, paint, "tree pitch/gum", cordage	1920 CE collected	Insect Lac - probable	Parker, Colorado River Reservation, La Paz County, AZ	(Spier 1955:8)
NMAI	.10/2715	Rattle		Mohave (Mojave)	Gourd, wood, mesquite, paint	1920 CE collected	Insect Lac - probable	Needles, San Bernadino Co., CA	(Quinn 1965)
NMAI	.10/2639	Rattle		Mohave (Mojave)	Gourd, wood, paint, "tree pitch/gum", mesquite	1920 CE collected	Insect Lac - probable	Parker, Colorado River Reservation, La Paz County, AZ	(Quinn 1965)
NMAI	.10/2642	Rattle		Mohave (Mojave)	Gourd, wood, asphaltum/bitumen, mesquite, twine/string	1920 CE collected	Insect Lac - possible, requires further analysis	Parker, Colorado River Reservation, La Paz County, AZ	(Quinn 1965)
NMAI	13/4193	Gum/ Pitch/ Resin		Northern Paiute (Paviotso)	Resin, wood	1924 CE collected	Insect Lac - possible, requires further analysis	Stillwater, Fallon Reservation (Stillwater Reservation); Churchill County; NV	
NMAI	.2/9532	Knife		Paiute, Kaibab	Wood, stone, adhesive resin	1875 CE collected	Insect Lac - possible, requires	Arizona, Northwestern	

							further analysis		
NMAI	13/4096	Fish spear		Paiute, Northern. (Paviotso)	Wood, animal bone, cordage, "tree pitch/gum"	1924 CE collected	Insect Lac - possible, requires further analysis	Pyramid Lake Reservation; Washoe County; NV	
NMAI	2/382	Knife		Paiute, Southern	wood, stone, pitch, gum	1860-1870 CE made	Insect Lac - possible, requires further analysis	Utah, South	Fowler and Matley 1979: 68-69, 156, 157)
NMAI	14/1788	Dice		Paiute, Southern, Moapa	Animal bone, hide(?) possible resin instead	1925 CE collected	Insect Lac - possible, requires further analysis	Moapa River Reservation, Clark Co. NV	
NMAI	14/1787	Dice		Paiute, Southern, Moapa	Nuts (walnut) "tree pitch/gum"	1925 CE collected	Insect Lac - possible, requires further analysis	Moapa River Reservation, Clark Co. NV	
NMAI	14/1853	Gum/ Pitch/ Resin		Paiute, Southern, Moapa	Insect Lac	1925 CE collected	Insect Lac	Moapa, Moapa River Reservation; Clark County; NV	
NMAI	.8/9830	Gum/ Pitch/ Resin		Papago (Tohono O'odham)	Insect lac, wood	1919 CE collected	Insect lac	Gu Achi (Santa Rosa), Tohono O'odham Reservation; Pima County; AZ	(Fontana et al. 1962: 80-81, 118)
NMAI	.8/9723	Jar, Pottery		Papago (Tohono O'odham)	Ceramic, insect lac	1910 CE	Insect Lac	Ali Chukson (Little Tucson), Tohono O'odham Reservation; Pima County; AZ	(Fontana et al. 1962: 80-81, 118)

NMAI	.8/9724	Jar, Pottery		Papago (Tohono O'odham)	Ceramic, insect lac	1919 CE collected	Insect Lac	Ali Chukson (Little Tucson), Tohono O'odham Reservation; Pima County; AZ	(Fontana et al. 1962: 80-81, 118)
NMAI	.8/9735	Jar, Pottery		Papago (Tohono O'odham)	Ceramic, insect lac	1919 CE collected	Insect Lac	Gu Achi (Santa Rosa), Tohono O'odham Reservation; Pima County; AZ	(Fontana et al. 1962: 80-81, 118)
NMAI	.8/9722	Jar, Pottery		Papago (Tohono O'odham)	Ceramic, insect lac	1919 CE collected	Insect Lac	Anakin, Tohono O'odham Reservation; Pima County; AZ	(Fontana et al. 1962: 80-81, 118)
NMAI	.8/9730	Jar, Pottery		Papago (Tohono O'odham)	Ceramic, insect lac	1919 CE collected	Insect Lac	Topawa, Tohono O'odham Reservation, Pima Co., AZ	(Fontana et al. 1962: 80-81, 118)
NMAI	.8/9721	Jar, Pottery		Papago (Tohono O'odham)	Ceramic, insect lac	1919 CE collected	Insect Lac	Gu Achi (Santa Rosa), Tohono O'odham Reservation; Pima County; AZ	(Fontana et al. 1962: 80-81, 118)
NMAI	.8/9725	Jar, Pottery		Papago (Tohono O'odham)	Ceramic, insect lac	1919 CE collected	Insect Lac	Ali Chukson (Little Tucson), Tohono O'odham Reservation; Pima County; AZ	(Fontana et al. 1962: 80-81, 118)
NMAI	.8/9264	Jar, Pottery		Pima (Akimel O'odham)	Ceramic, insect lac	1919 CE collected	Insect Lac - probable	Blackwater, Gila River Reservation; Pinal County; AZ	(Russell 1908:131).

NMAI	.12/9682	Rattle		Pima Bajo (Nevome)	Gourd, wood, adhesive	1924 CE collected	Insect Lac - probable	Ónavas Municipality, Sonora, Mexico	(Quinn 1965)
NMAI	.12/9683	Rattle		Pima Bajo (Nevome)	Gourd, wood, adhesive	1924 CE collected	Insect Lac - probable	Ónavas Municipality, Sonora, Mexico	(Quinn 1965)
NMAI	.12/9684	Rattle		Pima Bajo (Nevome)	Gourd, wood, paint, adhesive	1924 CE collected	Insect Lac - probable	Ónavas Municipality, Sonora, Mexico	(Quinn 1965)
NMAI	20/3245	Amulet		Seri (Comcáac)	Tree pitch/gum	1932 CE collected	Insect Lac	Bahía de Kino (Kino Bay); Hermosillo Municipality; Sonora State; Mexico	(Felger and Moser, 1991: 237)
NMAI	20/3247	Amulet		Seri (Comcáac)	Tree pitch/gum	1932 CE collected	Insect Lac	Bahía de Kino (Kino Bay); Hermosillo Municipality; Sonora State; Mexico	(Felger and Moser, 1991: 237)
NMAI	.11/2234	Gum/Pitch/ Resin		Seri (Comcáac)	Insect lac	1922 CE collected	Insect Lac	Isla Tiburón; Hermosillo Municipality; Sonora State; Mexico	(Felger and Moser, 1991: 128-130; Sheridan and Parezo 1996: 206)
NMAI	.12/9692	Gum/Pitch/ Resin		Seri (Comcáac)	Insect lac	1924 CE collected	Insect Lac	Isla Tiburón; Hermosillo Municipality; Sonora State; Mexico	(Felger and Moser, 1991: 128-130; Sheridan and Parezo 1996: 206)
NMAI	24/8475	Gum/ Pitch/ Resin		Seri (Comcáac)	Resin	1965-1970 CE collected	Insect Lac - possible, requires further analysis	Sonora, Mexico	(Felger and Moser, 1991: 128-130; Sheridan and Parezo 1996: 133)
NMAI	.12/9789	Harpoon head		Seri (Comcáac)	Wood, Iron, adhesive resin	1924 CE collected	Insect Lac - possible, requires	Isla Tiburón; Hermosillo Municipality;	(Felger and Moser, 1991: 128-130; Sheridan and

							further analysis	Sonora State; Mexico	Parezo 1996: 128-129)
NMAI	.10/2637	Harpoon head		Seri (Comcáac)	Wood, iron, cordage, adhesive resin	1924 CE collected	Insect Lac - possible, requires further analysis	Isla Tiburón; Hermosillo Municipality; Sonora, Mexico	(Felger and Moser, 1991: 128-130; Sheridan and Parezo 1996: 128-129)
NMAI	.11/2232	Jar		Seri (Comcáac)	Ceramic, adhesive resin	1922 CE collected	Insect Lac - probable	Isla Tiburón; Hermosillo Municipality; Sonora State; Mexico	(Felger and Moser, 1991: 92)
NMAI	16/4324	Jar with cover		Seri (Comcáac)	Ceramic, stone, adhesive resin	1929 CE collected	Insect Lac - probable	Seri Indian area; Sonora State; Mexico	(Euler and Jones 1956)
NMAI	20/3219	Spear point		Seri (Comcáac)	Wood, Iron, adhesive resin	1932 CE collected	Insect Lac - possible, requires further analysis	Bahía de Kino (Kino Bay); Hermosillo Municipality; Sonora State; Mexico	(Felger and Moser, 1991: 128-130; Sheridan and Parezo 1996: 128-129)
NMAI	21/4630	Vessel		Seri (Comcáac)	Ceramic, adhesive resin	1950 CE purchased	Insect Lac - probable	Isla Tiburón; Hermosillo Municipality; Sonora State; Mexico	(Felger, Richard and Mary Beck Moser, 1991: 92; Euler and Jones 1956)
NMAI	25/2678	Jar, Pottery		Tarahumara (Rarámuri)	Ceramic, hide, babiche, "tree pitch/gum"	1986 CE collected	Insect Lac - possible, requires further analysis	Río Batopilas (Batopillas) drainage; Chihuahua State; Mexico	
NMAI	.10/6497	Rattle		Yaqui (Yoeme), Pascua	Gourd, wood, "tree pitch/gum", paint	1921 CE collected	Insect Lac - probable	Tucson area, Pima Co., AZ	(Quinn 1965)
NMAI	.10/6496	Rattle		Yaqui (Yoeme), Pascua	Gourd, wood, twine/string, "tree pitch/gum"	1921 CE collected	Insect Lac - probable	Tucson area, Pima Co., AZ	(Quinn 1965)

NMAI	17/6551	Gum/ Pitch/ Resin		Yuma (Quechan)	Insect Lac	1930 CE collected	Insect Lac	Arizona, California (at the border of, possibly?) Yuma is in Arizona.	
NMAI	.8/8629	Rattle		Yuma (Quechan)	Wood, cordage, tree pitch/gum	1918 CE collected	Insect Lac	Arizona	(Castetter 1951; Spier 1933)
NMAI	21/4595	Rattle		Yuma (Quechan)	Wood, gourd, "tree pitch/gum"	1950 CE purchase d	Insect Lac - probable	Arizona	Castetter, E.F., Castetter 1951; Spier 1933)
NMNH	E7528-0	Cement for watertight baskets		Apache	Insect lac	1868 CE	Insect lac	Arizona	
NMNH	E76146-0	Gum of Arrow Weed		Cocopah (Cucapá)	Insect lac, Tachardiella pustulata on Pluchea sericea	1885 CE collected	Insect lac	Arizona	(McVaugh 1956: 275)
NMNH	E22704-0	Ladle, Pottery		Mohave (Mojave)	ceramic, pigment, insect lac	1876 CE	Insect Lac - possible, requires further analysis	Arizona	
NMNH	E10319-0	Pot for keeping seeds		Mohave (Mojave)	Insect lac	1870 CE Collected	Insect lac	Ft. Mohave, Mohave Agency, Colorado River, Arizona	(McVaugh 1956: 181; Castetter 1951: 160; Euler and Jones 1956)
NMNH	E24160-0	Rattle		Mohave (Mojave)	Gourd, wood, paint, Insect lac	1875 CE collected	Insect lac	California, Southern	(McVaugh 1956: 181; Castetter 1951: 116)
NMNH	E10320-0	Water vessel		Mohave (Mojave)	Insect lac	1870 CE Collected	Insect lac	Ft. Mohave, Mohave Agency, Colorado River, Arizona	Stewart 1983 Fig 7. 62; McVaugh 1956: 181; Castetter 1951: 160; Euler and Jones 1956)
NMNH	E14343-0	Flat pieces of cement (2)		N/A (Paiute Southern?)	Insect lac	1874 CE	Insect lac	Utah, South	
NMNH	E14338-0	Gum resin		Paiute	Insect lac	1874 CE	Insect lac	Utah, South	

NMNH	E14782-0	Larrea Mexicana Twigs & Gums		Paiute, Southern	Tachardiella larreae on Larrea tridentata twigs	1874 CE	Insect lac	Utah, South	(Fowler and Matley, 1979: 77)
NMNH	E14329-0	Stone knife with handle		Paiute, Southern	Wood, stone, resin	1874 CE	Insect Lac - probable	Utah, South	(Fowler and Matley, 1979: 68-69, 156, 157)
NMNH	E14784-0	Jar, Pottery		Paiute, Southern	ceramic, insect lac	1874 CE	Insect lac	Utah, South	
ASM	1977-33-270	Jar, Pottery		Tarahumara (Rarámuri)	Ceramic, wood, metal, insect lac, pine resin	1958 CE	Insect lac, pine resin	Labarachi, Chihuahua, Mexico	
NMNH	E14785-0	Jar, Pottery		Paiute, Southern, Moapa	ceramic, pigment, insect lac	1874 CE	Insect lac	Utah, South	(Fowler and Matley, 1979: 84)
NMNH	E165099-0	Gum cement		Panamint (Koso, Timbisha Shoshone)	Insect lac	1892	Insect lac	Panamint Mountains, Inyo County, California	(Coville 1892: 361)
NMNH	E175047-0	Arrows (3)		Pima (Akimel O'odham)	Wood (mesquite), feather, stone, sinew, insect lac	1894 CE collected	Insect Lac	Arizona, Southern	(McGee 2000)
NMNH	E218084-0	Awl		Pima (Akimel O'odham)	Insect lac, wood or metal	1902 CE	Insect lac	Sacaton, Gila River Indian Community, Pinal County, AZ	(Russell 1908: 106)
NMNH	E217981-0	Creosote bush gum		Pima (Akimel O'odham)	Insect lac, Tachardiella larreae on Larrea tridentata	1901 CE collected	Insect lac	Sacaton, Gila River Indian Reservation, Pinal County, AZ	(Russell 1908: 131)
NMNH	E76016-0	Football, wooden		Pima (Akimel O'odham)	Wood, resin coating, probably insect lac	1885 CE collected	Insect Lac - probable	Arizona	(Bahr 1983: 191; Culin 1907: 671-675; McVaugh 1956: 275)

NMNH	E76014-0	Footballs (2)		Pima (Akimel O'odham)	Stone, insect lac	1885 CE collected	Insect lac	Arizona	(Bahr 1983: 191; Russell 1908:172-173; Culin 1907: Fig.901, p. 679; McVaugh 1956: 275)
NMNH	E218045-0	Footballs (5)		Pima (Akimel O'odham)	Wood, stone, cloth, insect lac	1901 CE collected	Insect lac	Sacaton, Gila River Indian Community, Pinal County, AZ	(Russell 1908:172-173. Culin 1907: 671-675)
NMNH	E218083-0	Gum for mending		Pima (Akimel O'odham)	Insect lac, Tachardiella larreae	1901 CE collected	Insect lac	Sacaton, Gila River Indian Reservation, Pinal County, AZ	(Russell 1908:131)
NMNH	E27847-0	Wooden ball coverd with mesquite gum		Pima (Akimel O'odham), Maricopa (Piipaash)	Wood, resin coating, probably insect lac	1877 CE collected	Insect Lac - probable	Arizona	(Culin 1907: 671. Figure 895, p. 675)
NMNH	E174482-0	Harpoon-point		Seri (Comcáac)	Adhesive resin	1894-1895	Insect Lac - possible, requires further analysis	Sonora, Mexico	(McGee and Hewitt 1898: 187)
NMNH	E429881-0	Insect Exudate		Tarahumara (Rarámuri)	Zoological material, possibly insect lac	Early - mid 1980s	Insect Lac - possible, requires further analysis	Polanco Area, Chihuahua, Mexico	
NMNH	A335158-0	Scraper, bone, inlaid	Pueblo Bonito, Chaco Canyon	Ancestral Puebloan	Bone -Humerus of mule deer (Odocoileus hemionus), Stone (turquoise and Jet), Shell abalone	700-1130 CE	Insect lac	San Juan County, NM	2021 Artifact Query, March 7, 2021. The Chaco Research Archive (http://www.chacoarchive.org); Pepper 1905; Pepper 1909; Pepper 1920; Anderson 2019)

					(haliotis) adhesive resin				
NMNH	A335157-0	Scraper, bone, inlaid	Pueblo Bonito, Chaco Canyon	Ancestral Puebloan	Bone -Humerus of mule deer (Odocoileus hemionus), Stone (turquoise and Jet), Shell abalone (haliotis) adhesive resin	700-1130 CE	Insect lac, heavily heated	San Juan County, NM	2021 Artifact Query, March 7, 2021. The Chaco Research Archive (http://www.chacoarchive.org); Pepper 1905; Pepper 1909; Pepper 1920; Anderson 2019)Of Nebraska, Lincoln.
NMNH	A335725-0	Mosaic	Pueblo Bonito, Chaco Canyon	Ancestral Puebloan	Shell (deteriorated), stone (turquoise)		Insect lac, heavily heated probably	San Juan County, NM	2021 Artifact Query, March 7, 2021. The Chaco Research Archive (http://www.chacoarchive.org). Pepper 1920; Judd, and Allen 1954:104)
PHM	.1-10960	Gum for painting arrows		Chemehuevi	Gum	1907 CE collected	Insect Lac - possible, requires further analysis	Cabazon Reservation, Riverside County, CA	
PHM	.3-2975	Gum, arrowweed (Pluchea sericea)		Cocopah (Cucapá)	Insect lac on branch	1926 CE collected	Insect Lac	Sonora or Baja California, Lower Colorado river, Cocopa, Mexico	(Gifford 1933)
PHM	.1-4362	Rattle		Mohave (Mojave)	Gourd, wood, paint, "pitch"	1904 CE collected	Insect Lac - probable	Southwest	(Spier 1955: 8)
PHM	.1-4325	Rattle		Mohave (Mojave)	Gourd, wood, "pitch"	1904 CE collected	Insect Lac - probable	Southwest	(Spier 1955: 8)
PHM	.1-16603	Rattle		Mohave (Mojave)	Gourd, wood, "pitch" shoestring	1910 CE collected	Insect Lac - probable	Needles, San Bernadino Co., CA	(Spier 1955: 8)
PHM	.1-19767	Creosote gum		Mojave?	Insect lac on stem	c. 1900s	Insect Lac	California, Southern	(Austin, Mary 1903)

PHM	.3-14554	Rattle		Tipai-Ipai (Kumeyaay)	Gourd, wood, string, adhesive resin	1951 CE collected	Insect Lac - probable	La Huerta de Los Indios, Baja California state, Mexico	(Gifford 1931: 44; Wilken-Robertson, 2018)
PHM	.2-11652	Awl, bone with gum handle	Grapevine Canyon	Patayan/Mojave?	Bone, resin	Prehistoric	Insect Lac - possible, requires further analysis	NV-Cl-136, Clark County, NV; Grapevine Canyon, 8 miles west of Tri-state crossing, Nevada	(Stone 1987)
PHM	.2-11653	Awl, bone with gum handle	Grapevine Canyon	Patayan/Mojave?	Bone, resin	Prehistoric	Insect Lac - possible, requires further analysis	NV-Cl-136, Clark County, NV; Grapevine Canyon, 8 miles west of Tri-state crossing, Nevada	(Stone 1987)
PHM	.2-3142a-k	Mosaic pieces		Ancestral Puebloan	stone, ceramic	1882-1883 CE collected	Insect Lac - probable	Southwest	
PMAE	44-54-20/15009	Gourd rattle, handle attached with black resin, probably lac		Cocopah (Cucapá)	Gourd, wood, paint, resin	1944?	Insect Lac - probable	La Gruilla (near) Tabasco, Sonora, Mexico	
PMAE	76-20-10/10082	Native gum (larrea mexicana); canteria larreae deposited by scale		Mohave (Mojave)	Insect lac	1876 CE	Insect Lac	North America/ United States	
PMAE	76-20-10/10083	Prepared gum (larrea mexicana)		Mohave (Mojave)	Insect lac	1876 CE	Insect Lac	North America/ United States	
PMAE	12-29-10/84370	Rattle		Mojave	Rattle, split shaft, resin haft (probably insect	1912	Insect Lac - probable	North America/United States	(Spier 1955: 8)

					lac), perforated gourd head, twine loop handle				
PMAE	76-20-10/10102	Rattle		Mojave	Rattle, wood shaft, resin haft (probably insect lac), perforated gourd head	1875/76	Insect Lac - probable	North America/United States	(McVaugh 1956)
PMAE	76-20-10/9442	Gum of sarrea mexicana [sic]		Paiute, Southern	Wood, insect lac	1875 CE	Insect Lac	Utah, South	(McVaugh 1956:68)
PMAE	56-28-20/19805	Arrows (2) compound shaft		Seri (Comcáac)	Arrows, triangular metal points, wood and reed shafts, pigment, feather, resin (probably lac)		Insect Lac - probable	Tecomate, Tiburon Island, Sonora, Mexico	
PMAE	34-24-10/3711	Arrowweed arrow, stone points		Southern Paiute, Chemehuevi	Pluchea sericea stem, resin, feather, sinew, stone, paint, blood	1933	Insect Lac	Parker, La Paz County, Arizona	(Fowler and Garey-Sage 2016)
PMAE	34-24-10/3710	Cane arrows for big game, foreshaft arrowweed		Southern Paiute, Chemehuevi	Pluchea sericea stem, resin, feather, sinew, stone, paint, blood	1933	Insect Lac	Parker, La Paz County, Arizona	(Fowler and Garey-Sage 2016)
PMAE	34-24-10/3702	Awl, bone with creosote bush gum		Southern Paiute, Chemehuevi	Insect lac, Tachardiella larreae	1933	Insect lac	Parker, La Paz County, Arizona	(Kelly 1964:101)
PMAE	34-24-10/3731	Barbed stick for hooking chuck-wallas from		Southern Paiute, Chemehuevi	Wood shaft, bone barb attached with resin (lac from creosote)		Insect Lac	Parker, La Paz County, Arizona	(Fowler and Garey-Sage 2016:77)

		between rocks							
PMAE	34-24-10/3722	Gourd rattle, handle attached with gum from creosote bush		Southern Paiute, Chemehuevi	Gourd, wood, resin (insect lac), gum	1933	Insect lac	Parker, La Paz County, Arizona	(Fowler and Garey-Sage 2016)
PMAE	34-24-10/3708	Gum, Creosote bush		Southern Paiute, Chemehuevi	Insect Lac	1933	Insect Lac	Parker, La Paz County, Arizona	(Fowler and Garey-Sage 2016)
PMAE	34-24-10/3709	Gum, creosote bush, paint		Southern Paiute, Chemehuevi	Insect Lac, mineral paint	1933	Insect Lac	Parker, La Paz County, Arizona	(Fowler and Garey-Sage 2016)
PMAE	34-24-10/3761	Model barbed stick for hooking chuckwallas		Southern Paiute, Chemehuevi	Wood shaft with wood barb attached with resin (lac from creosote)	1933	Insect Lac	Las Vegas, Clark County, Nevada	(Fowler and Garey-Sage 2016:77)
PMAE	2004.16.20.2	Arrow making kit		Tarahumara (Rarámuri)	Insect lac	1989	Insect Lac	Chihuahua, Mexico	
PMAE	31-8-10/A7337	Shell bracelet	Los Muertos	Hohokam	Shell, turquoise, black paint or resin mastic (probably insect lac)	1886-1889	Insect Lac - probable	Salado Valley, Lower, Maricopa Co., Arizona	(Haury 1945: 156-158)
PMAE	46-73-10/44262	Shell bracelet	Los Muertos	Hohokam	Shell (Glycymeris), stone (turquoise), insect lac	1886-1889	Insect Lac - probable	Salado Valley, Lower, Maricopa Co., Arizona	(Haury 1945: 156-158)
PMAE	46-73-10/44263	Shell ring	Los Muertos?	Hohokam	Shell ring, univalve, painted and incised, inlayed w/ turquoise using "pitch or	1886-1889	Insect Lac - probable	Salt River Valley, Salado, Lower, Maricopa Co., Arizona	(Haury 1945: 156-158)

					tar" probably insect lac instead				
PMAE	46-73-10/44264	Conus Shell Pendant	Los Muertos?	Hohokam	Shell pendant, univalve, carved, painted in red and black with turquoise inlay, probably lac	1886-1889	Insect Lac - probable	Salt River Valley, Salado, Lower, Maricopa County, AZ	(Haury 1945: 156-158)
PMAE	46-73-10/57112	Shell fragments, worked	Los Muertos	Salado	Organic, shell, worked fragments, carved and painted, possibly part of a ring	1886-1889	Insect Lac - probable	Salt River Valley, Maricopa County, AZ	(Haury 1945: 156-158)
PMAE	46-73-10/55276	Jar, Pottery, Gila Plain or Piman	Los Muertos	Salado (Probably historic Piman)	Ceramic, insect lac	1886-1889	Insect Lac - probable	Salt River Valley, Maricopa Co., Arizona	(Haury 1945: 105-106, 193, Pl. 23)
PMAE	15-11-10/A2133	Bone dice (11) in skin bag	Cave 1, Burial Cave	Basketmaker II	Organic, hide bag bound with twine, circular and oval bone objects	1915	Insect Lac - possible, requires further analysis	Marsh Pass, Kin boo koo (Kinboko) Canyon, Navajo Co., Arizona	
PMAE	46-73-10/44265	Shell ring	Los Guanacos	Hohokam	Shell ring, univalve, carved, painted in red and black with turquoise inlay, probably lac		Insect Lac - probable	Salt River Valley, Salado, Lower, Maricopa County, AZ	(Haury 1945: 178)
SP	FS#8434	Mosaic pendant or Bullroarer	Salmon Pueblo	Ancestral Puebloan	Bone, hematite, turquoise, adhesive resin		Insect Lac - possible, requires further analysis	Salmon Pueblo/Ruins Museum	
TARL	GP-16230 (ASM#)	Knife, hafted	Ceremonial Cave?	Jornada Mogollon	Wood, stone, adhesive resin	1932 CE collected	Insect Lac - possible,	Texas	(Sayles 1935)

							requires further analysis		
TUZI	TUZI 1349	Mosaic pendant	Tuzigoot Pueblo	Sinagua, Southern	Stone (turquoise, argillite) shell, adhesive resin	1000-1425 CE	Insect Lac - possible, requires further analysis	Tuzigoot National Monument, Clarkdale, Yavapai Co., AZ	(Caywood and Spicer 1935: 87 – 88; Hedquist 2017: 376)
TUZI	TUZI 133	Mosaic	Tuzigoot Pueblo	Sinagua, Southern	Stone (turquoise) adhesive resin	1000-1425 CE	Insect Lac - possible, requires further analysis	Tuzigoot National Monument, Clarkdale, Yavapai Co., AZ	(Caywood and Spicer 1935: 87 – 88; Hedquist 2017: 376)
UPENN	17356	"Aree", Food		Tarahumara (Rarámuri)	Insect lac, Tachardiella fulgens on Coursetia glandulosa	1890s	Insect lac	Barancas (Canyons)	
UPENN	29-42-729	Drill point		Basketmaker	Wood, stone, sinew, resin, possibly lac	Prehistoric	Insect Lac - possible, requires further analysis	Southeastern Utah	
UPENN	29-42-217	Awl		Prehistoric Southwest	Bone carved awl with black "gum" adhering to it	Prehistoric	Insect Lac - possible, requires further analysis	Southeastern Utah, San Juan Drainage	(Osborne 2004)
UPENN	29-42-668	Knife		Prehistoric Southwest	Wood, stone (chalcedony), "gum" resin	Prehistoric	Insect Lac - possible, requires further analysis	Southeastern Utah, Lake Canyon	(Osborne 2004 Figure 248, pp. 396; 399)
UPENN	29-42-674	Drill		Prehistoric Southwest	Wood, stone, sinew, "gum"	Prehistoric	Insect Lac - possible, requires further analysis	Southeastern Utah, Red Canyon	(Osborne 2004 Fig.247e, p. 393)

UPENN	29-42-667	Knife		Prehistoric Southwest	Wood, stone (quartzite), resin, cordage	Prehistoric	Insect Lac - possible, requires further analysis	Southeastern Utah, Lake Canyon	(Osborne 2004 Figure 248, pp. 396, 399)
UPENN	29-42-673	Blade		Prehistoric Southwest	Wood, stone, "gum" resin	Prehistoric	Insect Lac - possible, requires further analysis	Utah, Deep Canyon	(Osborne 2004)
WACC	LAME11 622	Biface	Lake Mead, Grapevine Wash	Upland Patayan	Stone, insect lac	901 - 1150 CE	Insect Lac		(McClellan et al. 1980; (Stone 1987))
WACC	LAME11 533	Wood, worked	Lake Mead, Grapevine Wash	Upland Patayan	Wood, reed, insect lac	900 - 1150 CE	Insect Lac	Grapevine Canyon Petroglyphs (AZ:F:14:98 ASM)	(McClellan et al. 1980; (Stone 1987))
WACC	CAGR326 0-A	Arrow	Casa Grande	Hohokam	Stone (chert), wood, sinew, reed, insect lac	1150 - 1450 CE	Insect Lac - probable	Casa Grande Ruins National Monument, Pinal Co., AZ	
WACC	CAGR470 2	Arrow	Casa Grande	Hohokam	Wood, stone (obsidian), sinew, insect lac	1150 - 1450 CE	Insect Lac - probable	Casa Grande Ruins National Monument, Pinal Co., AZ	
WACC	LAME10 716	Knife	Lake Mead, Rockshelter 1	Upland Patayan	Stone (chert), insect lac		Insect Lac		(McClellan et al. 1980; Harrington. July 1935-October 1936)
WACC	LAME10 885	Wood artifact	Lake Mead, Rockshelter 11	Upland Patayan	Wood, insect lac		Insect Lac		(McClellan et al. 1980)
WACC	LAME11 051	Biface	Lake Mead, Boulder Rockshelter	Upland Patayan	Stone, insect lac		Insect Lac		(McClellan et al. 1980)
YPM	YPM ANT 019118	Jar		Maricopa (Piipaash)	Ceramic, adhesive resin		Insect Lac - possible, requires	Gila River Indian Reservation, AZ	(Castetter and Bell, 1937: 14)

							further analysis		
YPM	YPM ANT 019064	Rattle		Maricopa (Piipaash)	Gourd, wood, cordate, arrowweed gum		Insect Lac	Arizona	
YPM	YPM ANT 005364	Awl		Paiute	bone, lacquer/pitch/resin, textile		Insect Lac - possible, requires further analysis	Utah, South	
YPM	YPM ANT 005362	Poinard		Paiute	Stone, wood, lacquer/pitch/resin		Insect Lac - possible, requires further analysis	Utah	
YPM	YPM ANT 015124	Knife		Ancestral Puebloan	Stone; wood; lacquer/pitch/resin; plant matter	c. 1200 CE	Insect Lac - possible, requires further analysis	Butler Wash, San Juan Co., UT	

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